JPRS 68599

8 February 1977

ECONOMICS AND OPERATION OF THE MARITIME FLEET

20000215 071

U. S. JOINT PUBLICATIONS RESEARCH SERVICE

NOTE

JPRS publications contain information primarily from foreign
newspapers, periodicals and books, but also from news agency
transmissions and broadcasts. Materials from foreign-language
sources are translated; those from English-language sources
are transcribed or reprinted, with the original phrasing and
other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets
[] are supplied by JPRS. Processing indicators such as [Text]
or [Excerpt] in the first line of each item, or following the
last line of a brief, indicate how the original information was
processed. Where no processing indicator is given, the infor-
mation was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are
enclosed in parentheses. Words or names preceded by a ques-
tion mark and enclosed in parentheses were not clear in the
original but have been supplied as appropriate in context.
Other unattributed parenthetical notes within the body of an
item originate with the source. Times within items are as
given by source.

The contents of this publication in no way represent the poli-
cies, views or attitudes of the U.S. Government.

PROCUREMENT OF PUBLICATIONS

JPRS publications may be ordered from the National Technical
Information Service, Springfield, Virginia 22151. In order-
ing, it is recommended that the JPRS number, title, date and
author, if applicable, of publication be cited.

Current JPRS publications are announced in Government Reports
Announcements issued semi-monthly by the National Technical
Information Service, and are listed in the Monthly Catalog of
U.S. Government Publications issued by the Superintendent of
Documents, U.S. Government Printing Office, Washington, D.C.
20402.

Indexes to this report (by keyword, author, personal names,
title and series) are available through Bell & Howell, Old
Mansfield Road, Wooster, Ohio, 44691.

Correspondence pertaining to matters other than procurement
may be addressed to Joint Publications Research Service,
1000 North Glebe Road, Arlington, Virginia 22201.

BIBLIOGRAPHIC DATA SHEET	1. Report No. JPRS 68599	2.	3. Recipient's Accession No.

4. Title and Subtitle

ECONOMICS AND OPERATION OF THE MARITIME FLEET

5. Report Date
8 February 1977

6.

7. Author(s)
P. I. Strumpe, O. A. Nivikov, Editors

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Joint Publications Research Service
1000 North Glebe Road
Arlington, Virginia 22201

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

As above

13. Type of Report & Period Covered

14.

15. Supplementary Notes

EKONOMIKA I EKSPLUATATSIYA MORSKOGO FLOTA, No 130, 1971, Leningrad

16. Abstracts

The report contains data on the proceedings of the Central Scientific-Research Institute of the Maritime Fleet.

17. Key Words and Document Analysis. 17a. Descriptors

USSR
Marine Engineering
Social Sciences
Economics

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group   13J   05C

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 99
Unlimited Availability Sold by NTIS Springfield, Virginia 22151	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (REV. 3-72)   THIS FORM MAY BE REPRODUCED   USCOMM-DC 14952-P72

JPRS 68599

8 February 1977

ECONOMICS AND OPERATION OF THE MARITIME FLEET

ECONOMICS AND OPERATION OF THE MARITIME FLEET

CONTENTS   PAGE

UDC 629.123:657.372.4.004.13

FUNDAMENTAL METHODOLOGICAL PREMISES ON DEVELOPING PRICE HANDBOOKS FOR RE-
VALUATING VESSELS OF THE MARITIME FLEET   pp 3-28

[Article by O. A. Novikov, Candidate of Economic Sciences]

[Text] It is impossible to revaluate the fixed capital of the national econ-
omy as of 1 January 1972 without developing normative methodological materi-
als, primarily, such as price handbooks for revaluating machines, equipment,
and transportation facilities.

The extremely extensive list of technical equipment used in the national
economy has made it necessary to enlist the services of more than 100 re-
search and designing organizations in developing such price handbooks. In
order to ensure their methodological uniformity, the USSR Council of Minis-
ters has entrusted the overall methodological guidance of the work of these
organizations on the compilations of the price handbooks, their appraised,
and approval to the USSR Central Statistical Administration. In this con-
nection, the USSR Central Statistical Administration has developed Methodo-
logical Directives [1], which are as follows:

1. The revaluation of the fixed capital is done according to the replace-
ment value, i.e., its replacement in terms of the present costs. The re-
placement value is determined for the entire inventory object, including its
machine components, assemblies, units, apparatus, etc.

2. The price handbooks must include the entire list of equipment contained
in the balance sheets of an enterprise, regardless whether or not the items
are produced by domestic industry, removed from production, or are imported
from abroad.

3. Price handbooks for technical equipment produced at the present time by
the USSR industry must show its full replacement value including its pre-
sent day costs, the cost of packing, containers, installation, storage ex-
penses, additional parts, and all other expenses necessary for creating a
fixed capital and making it operational.

The present-day costs are understood to be wholesale prices introduced on
1 July 1969 with consideration for their partial changes in 1968 and 1969,

1

and for some equipment for which there are no wholesale prices -- the prices approved by ministries or established by agreements between the suppliers and the customers.

4. For technical equipment removed from production (outdated) and imported, the price handbook must show the replacement value which is determined by comparison with analogous modern technical equipment produced in this country with a correction for the difference in the technical and economic operation indexes, i.e., with consideration for obsolescence of the second form.

The replacement value of equipment removed from production or imported is calculated on the basis of modern equipment produced domestically and having stable wholesale prices. Experimental or first samples of new equipment have, as a rule, temporary increased prices which cannot serve as a basis for determining the replacement value of equipment which was removed from production or is imported.

5. If there is no modern equipment analogous to outdated or imported equipment, then their replacement value could be determined by using the index of changes in wholesale prices as of 1 July 1967 in comparison with prices as of 1 July 1955 according to groups of equipment of the same type which is close with respect to the design and technicoeconomic characteristics.

6. The replacement value of modernized technical equipment is established with consideration for its technical and economic indexes achieved as a result of its modernization.

It is evident that the methodical instructions on the principles of compiling price handbooks developed by the USSR Central Statistical Administration are extremely universalized and do not allow for the specific characteristics of the reproduction of the fixed capital of individual sectors of the national economy. The problems of evaluating fixed capital with consideration for obsolescence of the second form are developed particularly inadequatly there In this connection, the development of price handbooks for concrete types of machines, equipment, and means of transportation, particularly, those of them which are complex engineering structures combined into a single inventory object or a complete complex of units of various purposes requires preliminary studies of many methodological problems. First of all, they include the peculiarities of the formation of prices on technical equipment of the sector of economy, the rate of improvements in the characteristic designs and technology, and the organization of the production of technical equipment. Finally, they include the modern level of technical and economic perfection of the production apparatus, the rate and economic results of its renovation, sources of reporducing technical equipment, economic effectiveness of new technical equipment, methods for calculating the devaluation rate of individual types of outdated equipment depending on its purpose and role in the production process, as well as the sspecific chatacteristics of its utilization.

2

Table 1
Distribution of Maritime Vessels of the Operating Fleet by Places of Their Construction as of 1 January 1969, Percent

Суда по их назначению (1)	(2) Доля судов в составе флота			
	отечественной постройки (3)	(4) импортных	(3) отечественной постройки	(4) импортных
	(5) по дедвейту		(6) по числу судов	
(7)Грузо-пассажирские	13,8*	86,2*	18,8	81,2
(8)Сухогрузные суда универсального назначения	20,5	79,5	12,8	87,2
(9)Балкеры	—	100	—	100
(10)Лесовозы	39,5	60,5	35,5	64,5
(11)Рефрижераторы	—	100	—	100
(12)Ледокольно-транспортные . .	69,2	30,8	66,7	33,3
(13)Танкеры	51,1	48,9	48,3	51,7
(14)Газовозы	—	100	—	100
(15)Ледоколы	43,2**	56,8**	60,9	39,1
(16)Буксиры	57,3**	42,7**	63,0	37,0
(17)Лоцманские	100*	—	100	—
(18)Служебно-разъездные катера	99,0*	1,0*	95,8	4,2

*By passenger capacity, persons.
**By power, effective horsepower.

Key: 1. Purpose of vessels
2. Percentage of vessels in the fleet
3. Domestically built
4. Imported
5. By deadweight capacity
6. By the number of vessels
7. Passenger-cargo carriers
8. General-purpose dry cargo ships
9. Bulk carriers
10. Lumber carriers
11. Refrigerator ships
12. Icebreaker-transportation ships
13. Tankers
14. Gas carriers
15. Icebreakers
16. Tugboats
17. Pilot boats
18. Service crew cutter launches

3

The Possibility of Using Current Prices of Domestically Built Vessels for Revaluating the Fleet

The possibility of using current prices of domestically built vessels for revaluating the fleet is determined by:

-- the degree of correspondence of current prices to the actual expenditures of the national economy on the reproduction of vessels of the maritime fleet;

-- the degree of correspondence of current prices of vessels of individual types to the average production expenses in the shipbuilding industry and to those technical and operational characteristics of vessels which determine the amount of expenses on their construction and economic effectiveness of their operation;

-- the presence of prices according to the list of vessels under construction which corresponds to the list of vessels of the operating fleet.

The production apparatus of the maritime fleet is reproduced by building vessels at domestic plants and by importing, chiefly from the CEMA member-countries. As can be seen from the data of Table 1, importation of vessels has determining significance for the reproduction of some types of vessels.

Specialization of the shipbuilding industry which has been accomplished in recent years in the CEMA member-countries predetermines the replenishment of the USSR's maritime fleet with foreign-built vessels.

Prices of domestically built vessels are actually formed on the basis of planned and factual production expenses and reflect individual cost of construction of a vessel (or two-three vessels of the series) when they are built at a given shipyard.

The prices of imported vessels are defined as the product of the contracted prices of the vessel in the currency of the contract multiplied by the exchange rate of the currency of the contract in relation to the ruble and by the factor characterizing the ratio of the domestic and world prices of vessels. As a result, there exist two separate levels of prices for maritime fleet vessels which, as follows from the data of Table 2, differ considerably.

This situation is a result of many factors. The most important of them are the fluctuation of prices of vessels abroad in accordance with the market conditions, their changes under the effect of inflation, differences in the prices of vessels in individual countries supplying them, conditions of the purchasing transaction, and changes in the exchange rate of the ruble as a result of the devaluation of foreign currency. This situation is also greatly affected by the fact that the factors characterizing the ratio of domestic and world prices of vessels are averaged and, consequently, do not fully reflect the real situation in some individual instances.

4

Table 2

Balance-Sheet Cost of Some Domestically Built and Imported Vessels Put into Operation in 1968

(1) Название судна	(2) Страна постройки	(3) Водоизмещение в грузу, т	(4) Мощность, э. л. с.	(5) Балансовая стоимость на 1/1 1969 г.	
				(6) судна в целом, млн. руб.	(7) на 1 т водоизмещения в грузу, руб.
(16) *Сухогрузные суда*					
„Антон Чехов" (8)	Югославия (17)	20 510	12 000	4,25	207
(9) „Комсомольская слава"	СССР (18)	18 321	9 000	7,44	406
„Новотроицк" (10)	Финляндия (19)	17 895	9 000	4,21	235
„Восточный" (11)	ГДР (20)	17 900	8 150	3,10	173
„Иркутск" (12)	ГДР (20)	16 450	9 600	3,68	224
„Жанна Лябурб" (13)	Польша (21)	16 450	9 600	3,52	214
„Иван Черных" (14)	СССР (18)	9 860	5 200	4,51	457
„Джурма" (15)	Польша (21)	9 530	5 450	2,17	228
(22) *Танкеры*					
„Актюбинск" (23)	Финляндия (19)	6 945	2 900	2,17	312
„Ногинск" (24)	СССР (18)	2 920	2 000	2,22	760

Key:
1. Name of vessel
2. Country where built
3. Loaded displacement, tons
4. Power, effective horsepower
5. Balance-sheet cost as of 1 January 1969
6. Whole vessel, million rubles
7. Per one tone of loaded displacement, rubles
8. "Anton Chekhov"
9. "Komsomol'skaya Slava"
10. "Novotroitsk"
11. "Vostochnyy"
12. "Irkutsk"
13. "Zhanna Lyaburb"
14. "Ivan Chernykh"
15. "Dzhurma"
16. Dry cargo vessels
17. Yugoslavia
18. USSR
19. Finland
20. GDR
21. Poland
22. Tankers
23. "Aktyubinsk"
24. "Noginsk"

5

The presence of two equivalent sources for the reproduction of the fleet with different principles of the formation and level of prices of vessels makes it necessary to bring forward the problem of substantiating such a price level for the revaluation of the fleet which would make it possible not only to make the evaluations uniform and comparable, but would correspond to the actual expenditures of the national economy on the reproduction of the maritime fleet.

Theoretical revaluation of the fleet can be done on the basis of prices reflecting the following levels of vessel costs:

-- of shipbuilding in the USSR;

-- of shipbuilding abroad;

-- average between actual costs of vessels built at home and abroad;

-- average between actual expenditures on buying domestically built vessels and expenditures of the national economy on buying foreign-built vessels.

The prices corresponding to the costs of building vessels in the USSR will, in their form, fully correspond to the principles contained in the methodological instructions of the USSR Central Statistical Administration. Their use for the revaluation creates the appearance of complete comparability of the evaluation of the fixed capital of the maritime fleet and those of other sectors of economy. However, this comparability is only superficial. In reality, the actual expenses on the reproduction of the fleet differ sharply from an evaluation because it is assumed that the entire fleet is reproduced at domestic plants.

If only a small part of the fleet were reproduced through importation, such an assumption would be acceptable. However, with the actual ratios of the domestically built and imported vessels, and with consideration that the importation of vessels will not lose its importance, this assumption is unjustifiable.

Considerable differences between the building costs of vessels at domestic and foreign shipyards lead to substantial differences between the building costs of vessels in the USSR and the expenses of the national economy on the importation of vessels. A changeover in the replenishment of the fleet entirely from the domestic shipbuilding industry would result in a rapid growth of the latter, which would become a powerful factor for lowering the costs of shipbuilding and the price of vessels.

The use of prices corresponding to the present level of building costs of vessels in the USSR in the revaluation of the fleet will not make it possible to establish the actual cost of the fleet and will overestimate the cost of the fixes capital of the maritime fleet in comparison with the evaluation of fixed capital in other branches of transportation and industry. As a

result of this, the purpose of revaluation will not be achieved and the idea of the effectiveness of the maritime fleet as an important source for replenishing the currency fund of the country will be distorted.

Such an evaluation of the fixed capital is also extremely unfavorable for the economy of this sector.

Evaluation by the level of the building costs of vessels at foreign shipyards is the lowest. Its use would contribute to an increase in competiveness of the maritime fleet. However, it contradicts the main goals and purposes of the revaluation of the fixed capital. Moreover, reflecting the expenses on the reproduction of the fleet through foreign shipyards, with the existing amortization norms, it will not make it impossible to accumulate means through amortization deductions for a complete restoration of the fleet. This level of evaluation would be acceptable if the USSR had a system of direct subsidies to the shipbuilding industry by means of which, as it is done in a number of foreign countries, the difference between the building costs at domestic and foreign shipyards would be covered.

Evaluation of the fleet by the average of buying domestically built vessels and vessels built abroad corresponds fully to the existing practice of forming capital investments for the reproduction of the fleet. Its advantage, among other points, is that it makes it possible, without any changes in the developed practice of forming capital investments through measures which are totally within the competence of the Ministry of the Maritime Fleet, to ensure the comparability of the evaluations of the revaluated fleet and vessels which will start operating 5-6 years later [2].

However, such evaluation will not ensure the comparability of the costs of the fixed capital of the maritime fleet and other sectors of the national economy. When the fleet is evaluated according to the construction cost of vessels in the USSR, the evaluation will be much higher than the actual expenses of the national economy, but it will be underestimated if the above-mentioned level is used.

Evaluation of the fleet according to the average cost between actual expenses on purchasing domestically built vessels and the expenses of the national economy on purchasing vessels built abroad will reflect most accurately the actual expenses of the national economy on the reproduction of vessels of the maritime fleet.

If we assume that the expenses of the national economy on importing vessels are the cost of the vessel obtained by multiplying the contract price in foreign currency rubles by the expenses necessary for obtaining one ruble of net non-currency proceeds from exporting the product and take the current prices of domestically built vessels at the initial value, then the factor of bringing them to the above level will be defined by the following formula:

$$k_y = \frac{C_0 + s_B C_{II}}{C_0 + C_{H.\,0}},$$ (1)

7

where C_O is the total amount of prices of domestically built vessels;

$C_И$ is the total amount of contract prices of imported vessels;

$C_{И.O}$ is the total amount of prices of imported vessels if they were produced by the domestic shipbuilding industry;

$s_в$ is the expenditure of Soviet currency by the national economy per one ruble of net foreign-currency proceeds from exporting;

This level of evaluation will raise the balance-sheet cost of imported vessels and, probably, the fixed capital of the maritime fleet, but, as a result, the fixed capital of the fleet will have an evaluation which will not only correspond to the actual expenditures of the national economy on the reproduction of vessels of the maritime fleet, but will also be comparable with evaluation of fixed capital of other sectors of the national economy and other types of transportation. Thus, this evaluation meets the requirements of the revaluation of the fixed capital of the national economy and, consequently, it should be used in developing price handbooks for vessels of the maritime fleet.

During the postwar years, the percentage of foreign-built vessels in the composition of the Soviet maritime fleet has been steadily decreasing. Comparison of data in Tables 1 and 3 shows that the ratio in the replenishment of the fleet with domestically built vessels and foreign vessels envisaged by the plan for the development of the material and technical resources of the maritime fleet for 1971-1975 will ensure further increase in the share of the domestic ship-building industry. On this basis and taking into consideration that the replacement value level is determined by the conditions of their reproduction and not by the conditions of their production in the past, the proportions of the reproduction of the fleet stated in the five-year plan should be used in calculating the evaluation level by formula (1). However, since the prices of vessels, particularly those of imported vessels, indicated in the plan are very approximate, it is expedient to do practical calculations of the evaluation level by the physical volume indexes of deliveries which are defined in the plan much more accurately than the costs. In this case calculations are done by the following formula:

$$k_y = \frac{D_0 + k_и s_в D_и}{D_0 + D_и},$$ (2)

where D_O is the total volume of domestically built vessels according to the plan for the development of the material and technical resources of the maritime fleet for 1971-1975;

$D_И$ is the total volume of the deliveries of imported vessels according to the plan for the development of the material and technical resources of the maritime fleet for 1971-1975;

$k_и$ is the factor reflecting the ratio of the world and domestic prices of the vessels.

Comparative analysis of the building costs of vessels in the USSR and in foreign countries with developed shipbuilding industries has shown [3] that the ratios of the domestic and world prices are not the same for vessels of various purposes. As a rule, the more complex the design of the vessels,

8

Table 3
Distribution of Sea-Going Vessels to Be Added in 1971-1975 by Places of Their Construction, Percent

Суда по их назначению (1)	Доля судов в составе флота (2)			
	отечественной постройки (3)	импортных (4)	отечественной постройки (3)	импортных (4)
	по дедвейту (5)		по числу судов (6)	
Сухогрузные суда универсального назначения . (7) . .	67,5	32,5	56,9	43,1
Лесовозы . (8)	30,4	69,6	24,8	75,2
Балкеры . . . (9)	40,6	59,4	22,5	77,5
Ледокольнс-транспортные суда . . (10)	100	—	100	—
Рефрижераторные суда (11)	—	100	—	100
Танкеры . . (12)	57,0	43,0	55,1	44,9
Газовозы . . . (13)	—	100	—	100
Виновозы . (14)	—	100	—	100
Танкеры для химических грузов . . . . (15)	—	100	—,	100

Key: 1. Purpose of vessels
2. Percentage of vessels in the fleet
3. Domestically built
4. Imported
5. By deadweight capacity
6. By the number of vessels
7. General-purpose dry cargo ships
8. Lumber carriers
9. Bulk carriers
10. Icebreaker-transportation ships
11. Refrigerator ships
12. Tankers
13. Gas carriers
14. Wine carriers
15. Tankers for chemical cargoes

the greater is the difference in the prices. The percentage of imported vessels in the replenishment of the fleet with vessels of individual purposes also differs. Therefore, the evaluation level should be determined separately for vessels of each type. However, in the practice of the maritime fleet operation, vessels of many different purposes are used to carry cargoes which do not correspond to their main specialization. Therefore, it is more expedient to differentiate the evaluation levels by the following groups: passenger and passenger-cargo carriers; cargo carriers; tugboats; icebreakers; self-propelled auxiliary service crafts; suction dredgers; hopper barges; non-self-propelled auxiliary service crafts and floating facilities.

The following could be taken as indexes of the delivery volume of vessels: for passenger and passenger-cargo vessels -- passenger capacity according to the number of cabin berths; for cargo vessels and for hopper barges -- deadweight, for tugboats, self-propelled auxiliary service crafts, and ice-breakers -- the power of main engines; for suction dredgers -- their output capacity.

In the present practice of price formation for maritime vessels, regardless of whether they are built at the shipyards of the Ministry of the Ship-Building Industry or of the Ministry of the Maritime Fleet, two stages are established.

The first stage is the determination of an approximate cost of the vessel on the basis of higher norms during the development of engineering projects by the designing organization. This cost is used for determining the planned production volumes and for preliminary settlement of accounts between the supplier and the customer as it is partially completed. Since the norms used in calculating the approximate cost of a vessel usually do not reflect adequately the peculiarities of its design, the errors in the determination of these costs are considerable. Due to this, the approximate costs are made more accurate when the vessel is 70-80 percent completed.

At the second stage, a stable price of the vessel is established. The price on the pilot vessel is established according to the actual costs in the cource of two months after the signing of the delivery note. A stable price on the first series-production vessels is established in the course of six months after the delivery of two series vessels whose construction was started before the delivery of the pilot vessel to the consumer. Stable prices for each subsequent group of series vessels (2-4 vessels) is established on the basis of actual building costs of the preceding group.

Thus, current prices on vessels built domestically are established separately for the pilot vessel and for a group of series vessels, and the price of each type reflects individual costs of the builder. This method of price formation is due to high expenses on preparing and setting up the production of vessels and the existing practice of including all these expenses in the cost of building the vessels for which the expenses were actually required. The high level of expenses on the setting up and preparation of production character-istic of the shipbuilding industry and considerable rates of their decrease, particularly for a small number of vessels following the pilot vessel, are determined by the specific peculiarities of this industry which include a considerable complexity of the designs of modern vessels, high labor inten-siveness and materials consumption in their construction within a relatively narrow area of jobs, and the necessity of extensive cooperation with other branches of industry. At the present time, it has been decided to create, in 1971, a fund for developing new construction projects in shipbuilding. This fund will be used to finance the preparation and development of the construction of vessels of new designs. This will make it possible, at least, to reduce sharply the number of steps, if not to eliminate them completely

Table 4

Table 4
Current Prices of Cargo Vessels of the Maritime Fleet

Тип судна (1)	Водоизмещение в грузу, т (2)	Тип главного двигателя (3)	Мощность главного двигателя, л. с. (4)	Завод-строитель (условный номер*) (5)	Порядковый номер судна в серии (6)	Цена судна в целом, тыс. руб. (7)	Стоимость 1 т водоизмещения, руб. (8)
Сухогрузные суда универсального назначения (9)							
(12) „Капитан Кушнаренко"	22 180	ДВС (10)	13 500	№ 1	Головное(11) / 8	11 250 / 8 300	506 / 374
(13) „Бежица"	18 500	ДВС	8 750	№ 2, № 1	15	6 950	376
(14) „Славянск"	18 320	ДВС	9 000	№ 2	4 / 10	7 320 / 7 170	399 / 391
(15) „Пятидесятилетие комсомола"	11 260	ДВС	5 400	№ 3	Головное / 2 / 4 / 6	9 000 / 7 400 / 7 200 / 7 000	798 / 657 / 640 / 622
(16) Новый проект	8 350	ДВС	3 850	№ 2	Головное	5 800	694
(17) „Тикси"	6 140	ДВС	2 000	№ 5	Головное / 2 / 10	3 500 / 2 900 / 2 500	570 / 471 / 407
(18) *Лесовозы*							
(19) „Вытегралес"	9 280	ДВС	5 200	№ 4	12 / 15 / 17	4 660 / 4 520 / 4 400	503 / 487 / 473
				№ 3	15 / 18 / 19	4 400 / 4 310 / 4 200	473 / 464 / 452

11

Table 4 Continued

(1) Тип судна	(2) Водоизмеще-ние в грузу, т	(3) Тип глав-ного дви-гателя	(4) Мощность, главного двигателя, у. с.	(5) Завод-строитель (условный номер)	(6) Порядковый номер судна в серии	(7) Цена судна в целом, тыс. руб.	(8) Стоимость 1 т водоизме-щения, руб.
(20) „Сибирьлес"	6 000	ДВС	2 900	№ 5	5	3 600	600
					7	3 450	575
(21) „Селигер"	3 745	ДВС	2 000	№ 4	Головное	4 250	1132
					2	3 325	885
					3	3 060	815
					4	2 970	790
					5	2 925	778
					7	2 880	768
					9	2 840	757
					10	2 750	733
(22) „Байкал"	2 290	ДВС (10)	1 000	№ 6	2	3 100	826
					3	3 000	800
				№ 7	(11) Головное	2 900	1265
					2	2 300	1005

Танкеры (26)

(1) Тип судна	(2) Водоизмеще-ние в грузу, т	(3) Тип глав-ного дви-гателя	(4) Мощность, главного двигателя, у. с.	(5) Завод-строитель (условный номер)	(6) Порядковый номер судна в серии	(7) Цена судна в целом, тыс. руб.	(8) Стоимость 1 т водоизме-щения, руб.
(23) „София"	62 600	ТС (27)	19 000	№ 8	12	10 100	161
					14	10 700	171
(24) „Великий Октябрь"	21 000	ДВС	9 000	№ 8	Головное	9 450	450
					7	7 940	378
					8	7 570	360
					9	7 210	343
					10	7 020	334
					11	6 900	329
				№ 9	Головное	9 700	462
					2	8 500	405
					4	7 950	379
					6	7 800	371
(25) „Мангышлак"	16 200	ДВС	5 000	№ 10	Головное	8 600	591
					2	7 000	432
					3	6 730	415
					4	6 500	401

12

Table 4 Continued

*Conventional numbers -- for the convenience of using the table.

Key: 1. Type of vessel
     2. Loaded displacement, tons
     3. Type of main engine
     4. Power of main engine, horsepower
     5. Shipyard (conventional number*)
     6. Number of vessel in the series
     7. Whole price of vessel, thousand rubles   18. Lumber carriers
     8. Cost of 1 ton of displacement, rubles   19. "Vytegrales"
     9. General-purpose dry cargo vessels   20. "Sibir'les"
    10. Internal combustion engine   21. "Seliger"
    11. Pilot   22. "Baykal"
    12. "Kapitan Kushnarenko"   23. "Sofiya"
    13. "Bezhitsa"   24. "Velikiy Oktyabr'"
    14. "Slavyansk"   25. "Mangyshlak"
    15. "Pyatidesyatiletiye Komsomola"   26. Tankers
    16. New project   27. Turbine
    17. "Tiksi"

[4]. As a result, the prices of domestic vessels are absolutely incomparable among them.

Table 4 shows current prices of cargo vessels built in the country which were obtained chiefly from the price handbook [5], as well as from the data of agreements for the delivery of vessels by the Ministry of the Maritime Fleet by the Ministry of the Shipbuilding Industry. Analysis of the prices confirms that they are incomparable because they are given for different numbers of vessels in the series. Just for this reason alone, their direct use for revaluating vessels of the maritime fleet will not make it possible to determine the replacement cost at the level of expenses in a developed series production and does not eliminate the existing incomparability of balance-sheet costs even for vessels of the same type.

These prices are also incommensurable in the case if, by using definite relations between the price of the vessel and its serial number in the series, they are recalculated for some other number of a vessel whose series production has been developed. Table 5 shows the results of the recalculation of prices shown in Table 4 in application to the fifteenth and the twentieth vessels in the series. It is evident that, in spite of the fact that the difference in the prices decreased, they are still not determined by the differences in the technical and operational characteristics of the vessels. For example, the cost of one ton of loaded displacement of general-purpose dry cargo vessels of a new project (W=8,350 tons) is 10 percent higher, of the type of "Pyatidesyatiletiye Komsomola" (W=11,260 tons) is 41 percent higher, and that of the "Bezhitsa"-type (W=18,500 tons) is 16 percent higher

Table 5

Prices of Cargo Vessels of the Maritime Fleet Recalculated According to the Conditions of Developed Series Production*

Тип судна (1)	Водоизмещение в грузу, т (2)	Тип главного двигателя (3)	Мощность двигателя, л. с. (4)	Завод-строитель (5)	Цена судна, тыс. руб. (6)	Стоимость 1 т водоизмещения, руб. (7)
(8) *Сухогрузные суда универсального назначения*						
„Капитан Кушнаренко" (11)	22 180	ДВС	13 500	№ 1	7 480	338
„Бежица" (12)	18 500	ДВС	8 750	№ 1, 2	6 950	376
„Славянск" (13)	18 320	ДВС	9 030	№ 2	6 665	364
„Пятидесятилетие комсомола" (14)	11 260	ДВС	5 400	№ 3	5 120	455
Новый проект (15)	8 350	ДВС	3 850	№ 2	2 960	355
„Тикси" (16)	6 140	ДВС	2 000	№ 5	1 985	323
(9) *Лесовозы*						
„Вытегралес" (17)	9 280	ДВС	5 200	№ 4	4 315	464
				№ 3	4 215	454
„Сибирьлес" (18)	6 000	ДВС	2 900	№ 5	2 850	475
„Селигер" (19)	3 745	ДВС	2 000	№ 4	2 310	616
				№ 6	2 105	562
„Байкал" (20)	2 290	ДВС	1 000	№ 7	1 500	655
(10) *Танкеры*						
„София" (21)	62 600	ТС	19 000	№ 8	10 240	164
„Великий Октябрь" (22)	21 000	ДВС	9 000	№ 8	6 760	322
				№ 9	6 400	305
„Мангышлак" (23)	16 200	ДВС	5 000	№ 10	5 700	352

*For vessels of over 10,000 ton displacement -- the fifteenth vessel, for others -- the twentieth vessel.

Key:
1. Type of vessel
2. Loaded displacement, tons
3. Type of main engine
4. Engine power, horsepower
5. Shipyard
6. Cost of vessel, 1000 rubles
7. Cost of 1 ton of displacement, rubles
8. General-puspose dry cargo vessels
9. Lumber carriers
10. Tankers
11. "Kapitan Kushnarenko"
12. "Bezhitsa"
13. "Slavyansk"
14. "Pyatidesyatiletiye Komsomola"
15. New project
16. "Tiksi"
17. "Vytegrales"
18. "Sibir'les"
19. "Seliger"
20. "Baykal"
21. "Sofiya"
22. "Velikiy Oktyabr'"
23. "Mangyshlak"

14

than that of a general-purpose dry cargo vessel of the "Tiksi"-type (W=6,140 tons). In the meantime, it is known that when the size of the vessel is greater, the proportionate value of its cost, including that for one ton of loaded displacement. must decrease. Due to this fact, the use of the current prices of domestically built vessels for the revaluation of the fleet cannot ensure the correspondence of the cost of vessels to their technical and operational characteristics and the socially necessary expenses on their construction, and, consequently, will not make it possible to regularize the balance-sheet evaluation of the vessels of the maritime fleet.

Direct utilization of current prices of domestically built vessels for revaluating the fleet is based on the possibility of evaluating vessels which are not produced at the present time by the domestic industry and imported vessels by comparing them with those vessels for which prices are available. But at the present time, for the transportation fleet, prices are available only for seven types of general-purpose dry cargo vessels (for two types -- only for pilot vessels), for four types of lumber carriers, for four types of tankers, for one type of icebreaker-transportation vessels, and one type of ferry boats. For the non-self-propelled and auxiliary service fleet, prices are available only for eleven types of dry cargo barges and six types of tanker barges. Still fewer prices are available for vessels of other purposes. For example, for the icebreaker fleet only the price for one type of port icebreaker is available.

Comparative analysis of the list of vessels of the operating fleet with the list of vessels on which prices are available indicates that this method cannot be used for revaluating not only individual series of vessels but also whole types of the fleet. For example, prices are not only unavailable for passenger-cargo ships of the transportation fleet, suction dredgers, and route-clearing icebreakers, but vessels of these types are not even built in the USSR at all at the time.

Most of all, prices are available for general-purpose dry cargo vessels. However, if we take into consideration that the cost of a vessel is affected by a great number of design factors (at least 10 of them can change the cost substantially, and the fleet has almost no vessels which are analogous in their designs to those on which prices are available), this evaluation method is unacceptable even for this type of fleet.

Thus, direct utilization of the current prices for revaluating the vessels of the maritime fleet will not make it possible to determine the replacement value of vessels not only at the level of the actual expenses of the national economy, but even at the level of average expenses of the shipbuilding industry, and does not eliminate the existing incomparability of the balance-sheet costs of the vessels of the operating fleet. In this connection, correct revaluation of the fleet can be done only on the basis of specially developed norms for vessel costs which would make it possible to calculate the cost of any vessel in the fleet. For standard vessels, the price handbooks should give the replacement value directly, however, it also must be calculated on the basis of the norms.

Principles of Developing Cost Norms for Maritime Vessels for Revaluating
the Fleet

The variety of problems requiring preliminary determination of the costs of
vessels for their solution made it necessary to have many methods for their
calculation. The selection of one or another method is determined by the
nature of the problem and the availability of the necessary initial data.
In application to the determination of the costs of vessels for revaluating
the fleet, this method must be suitable for all or the majority of types of
vessels and must ensure a sufficient degree of accuracy in determining the
replacement value of the vessels and uniformity of their evaluation, as well
as the utilization of norms for technical characteristics of vessels avail-
able in the production organizations, and a sufficient simplicity of cal-
culations. The possibility of fulfilling these requirements depends greatly
on the adopted system of the classification of vessels by their purposes and
on breaking up the vessel into structural groups, as well as on correct se-
lection of measuring criteria for individual structural groups and on the
establishment of a group of factors which must be taken into consideration
by using correction coefficients for the norms.

Analysis of the effect of the purpose of a vessel on the cost of its construc-
tion has shown that, for example, the norms for the revaluation of the trans-
portation fleet should be differentiated by the types of vessels: passenger-
cargo and passenger; general-purpose dry-cargo vessels; lumber carriers;
bulk carriers; refrigerators; icebreaker-transportation vessels; dry-cargo
ships for mixed navigation; shallow-draft tankers; gas carriers; train fer-
ries; automobile ferries; dry-cargo lighters; tanker-lighters; sea-going
dry-cargo barges; sea-going tanker barges.

Studies have shown that, for most types of vessels of the maritime transpor-
tation and port fleet, a sufficient degree of accuracy can be achieved in
determining their costs when the vessel is divided into the hull with its
equipment and the propulsion plant. Passenger vessels of the transportation
fleet are an exception. They need a different differentiation, just as small
self-propelled auxiliary service crafts, passenger vessels of the port fleet,
and nonself-propelled crafts, which can be evaluated, as a rule, on the basis
of one norm established for a unit of one of their technical and operational
characteristics.

Considerable difficulties arise in selecting a measuring criterion for the
norms for the cost of the hull with its equipment in cargo vessels. The
following criteria are possible in this case: deadweight, loaded displace-
ment, unloaded displacement, product of overall dimensions of the vessel,
gross registered tonnage, gross capacity of the holds. Qualitative analysis
did not make it possible to give preference to any one of them. Therefore,
the selection of the criterion was done on the basis of a quantitative evalu-
ation of the accuracy in the determination of the cost of the hull with its
equipment obtained in using each criterion. For this, correlation between
each of the above criteria and the cost of the hull with its equipment was

16

determined. The most reliable criterion is the one for which the correlation coefficient $|r|$ will be the highest with respect to its absolute value (in this case, $|r| \leqslant 1$).

The correlation coefficient was calculated by the formula:

$$r = \frac{\sum_{ji}(A_j - \bar{A})(C_{K_i} - \bar{C}_K)}{n \sigma_A \sigma_{C_K}},$$

(3)

where A_j is the value of the analyzed criterion of the j-th vessel;

$\bar{A}$ is the arithmetic mean value of this criterion for all vessels under study;

C_{k_i} is the cost of the hull with equipment of the i-th vessel;

$\bar{C}_k$ is the average cost of the hull with equipment of the vessels for which calculations are being done;

n is the number of vessels included in calculations;

σ_A is the root-mean-square of A;

σ_{C_k} is the root-mean-square of C_k.

The root-mean-square of A and C_k were determined by the following formulas:

$$\sigma_A = \sqrt{\frac{\sum_j (A_j - \bar{A})^2}{n}};$$

(4)

$$\sigma_{C_K} = \sqrt{\frac{\sum_i (C_{K_i} - \bar{C}_K)^2}{n}}.$$

(5)

Calculations have shown that the highest correlation value for cargo vessels is observed between the cost of the hull with the equipment and the gross registered tonnage of the vessel. Therefore, the gross registered tonnage was selected as a criterion of the norms for the cost of the hull with equipment. However, in order to achieve the necessary accuracy of evaluation, the use of this criterion requires correction coefficients for the presence of ice reinforcements and for the method of joining parts of the hull, as well as for the number of decks, the type of the propulsion plant, the speed, the automation level, the navigation area, and the location of the machine and boiler room.

The norms for the cost of the hull with equipment in ferries must be differentiated additionally depending on the presence of passenger quarters.

The norms for the cost of propulsion plants must be developed according to their types: steam engines, steam turbines, internal combustion engines, gas turbines (separately for turbines with free-moving piston gas generators and with gas formation in the combustion chamber). For all types of propulsion plants, it is necessary to consider the influence of the number of

17

engines and propeller shafts, the type of transmission*, and the type of accessory drive**. Moreover, for vessels with a steam engine, it is necessary to consider the type of boilers and the presence or absence of an exhaust steam turbine, for vessels with a steam turbine -- the type of boilers and steam parameters (temperature and pressure), and for vessels with a diesel engine -- the number of its revolutions per minute and the presence or absence of pressure charging and a compression unit, and the method of joining parts of the engine.

Due to the presence of clear relationship between the power of the main engines and the cost of power units, as well as on the basis of specifications available at enterprises, it is expedient to take the unit of power of the main engines (1 horsepower) as a criterion for the norms for the cost of power units.

Norms for the cost of individual structural units as well as for the entire vessel must be worked out at the level of their developed series production at domestic shipyards. When series production is set up, the expenses on the construction of vessels becomes stabilized and do not change much for subsequent vessels in the series. Analysis has shown that the tenth vessel for vessels over 4,000 tons, unloaded displacement, and the twentieth vessels for vessels below 4,000 tons can be considered as vessels in developed series production for the purpose of revaluating transportation vessels of the maritime fleet.

The possibility of using vessels of these numbers is confirmed by the data on series production of vessels for the Ministry of the Maritime Fleet at domestic and foreign shipyards which are shown in Table 6. It is evident that the actual series construction of vessels for the maritime fleet is, as a rule, much higher than 20 items.

Due to the fact that at the present time there is practically no specialization of shipyards by the types of vessels, cost norms for vessels can be comparable only if they are developed on the basis of construction costs in application to an individual shipyard.

Full expenses on the reproduction of items of the fixed capital include not only their cost but also expenses on the delivery, installation etc. In the case of vessels of the maritime fleet, they include expenses on ferrying the vessel from the shipyard to the port of registration.

In the case of cargo ships, in most instances there are no expenses on ferrying because most frequently they are loaded in a port nearest the place of construction. For all other vessels, expenses on ferrying must be included in the replacement value. Analysis has shown that the direct determination

---

* Steam engines and low-speed internal combustion engines are an exception.
**Only for tankers

Table 6
Series Construction of Maritime Vessels Built at Domestic and Foreign Shipyards

(1) Тип судна	(2) Число судов	(3) Дедвейт, т	(4) Мощность, э. л. с.	(5) Годы постройки	(6) Страна постройки
(7) *Сухогрузные суда универсального назначения*					
„Ильичевск" .(8) . .	33	221	300	1959—1963	СССР (26)
„Тельновск" (III, IV серия „Тиссы") .(9). .	54	1 133	800	1949—1959	Венгрия (27)
„Тарту" . . .(10). . .	47	1 324	1 000	1960—1963	Венгрия (27)
„Повенец" .(11). . .	40	4 150	3 250	1963—1967	ГДР (28)
„Андижан" .(12). . .	45	4 354	2 500	1958—1962	ГДР (28)
„Красноград"(13). . .	23	.12 200	9 000	1952—1967	Финляндия (29)
„Бежица" . .(14). . .	19	12 730	8 750	1963—1968	СССР (26)
„Ленинский комсомол" (15)	24	16 040	13 000	1959—1964	СССР (26)
(16) *Лесовозы*					
(17) „Котласлес" (I серия) .	25	3480/3819	2 900	1962—1968	Финляндия (29)
(18) „Инженер Белов" . . .	21	4016	1 600	1959—1963	СССР (26)
(19) „Беломорсклес"	64	5726/6036	5 450	1962—1968	Польша (30)
(20) „Вытегралес"	36	5970/6550	5 200	1963—1968	СССР (26)
(21) *Танкеры*					
„Аксай" . (22)	20	4 440	2 900	1961—1967	Финляндия (29)
„Инженер А. Пустошкин" .(23).	33	4 643	1 600	1957—1967	СССР, Болгария (31)
„Казбек" . (24). . . .	63	11 800	4 000	1951—1961	СССР (26)
„София" . . .(25). .	21	49 370	19 000	1963—1968	СССР (26)

Key:
1. Type of vessel
2. Number of vessels
3. Deadweight, tons
4. Power, effective horsepower
5. Years of Construction
6. Country where built
7. General-purpose dry-cargo vessels
8. "Il'ichevsk"
9. "Tel'novsk" (III, IV series of "Tissa")
10. "Tartu"
11. "Povenets"
12. "Andizhan"
13. "Krasnograd"
14. "Bezhitsa"
15. "Leninskiy Komsomol"
16. Lumber carriers
17. "Kotlasles" (I series)
18. "Inzhener Belov"
19. "Belomorskles"
20. "Vytegrales"
21. Tankers
22. "Aksay"
23. "Enzhener A. Pustoshkin"
24. "Kazbek"
25. "Sofiya"
26. USSR
27. Hungary
28. GDR
29. Finland
30 Poland

19

of the norms for these expenses by report data often give a distorted impression of their amount. Therefore, these norms must be calculated with consideration for the possibility of reproducing vessels for various purposes in individual marine basins and to differentiate them depending on the purpose of the vessel, its size, the method of delivering it to the place where it will be used, and the distance of its delivery.

Estimation of the Obsolescence Factor in Determining the Replacement Value of Vessels of Outdated Designs

Obsolescence of means of labor is their depreciation as a result of technical progress and can show itself in two forms. The first form is when obsolescence of items of the fixed capital is caused by the growth of labor productivity in the branches of production producing these items of the fixed capital. In the second form, obsolescence of the working means of labor is caused by the fact that items of analogous purposes are introduced into production which ensure a higher labor productivity, lower the cost of production, improve the quality of products etc.

In determining the replacement value of vessels by the norms based on the present level of expenses on the reproduction of the fleet, the obsolescence of the first form is taken into consideration automatically. But the obsolescence of the second form requires special methods for calculating the replacement value of vessels of outdated designs, and the degree of its effects on the evaluation of vessels of individual types and the fleet as a whole is determined primarily by the rate of the technical progress and the degree of the renovation of the fleet since the time of the preceding revaluation of the fixed capital.

In connection with the overall scientific and technical revolution in transportation, the maritime fleet has undergone radical changes in the last 10-12 years. The rate of its replenishment increased sharply since 1958. As a result of this, the tonnage of the transportation fleet of the Ministry of the Maritime Fleet increased by 2.05 times during 1961-1965, and in 1970 it will exceed the tonnage of 1965 by more than 1.5 times. The rapid rate of replenishment ensured not only a very considerable growth of the cargo fleet, but also a sharp change in the composition and structure of the fleet and its quality indexes. In 1960, there was a predominance of slow-going vessels of low and medium tonnage many of which had steam engines with boilers working on solid fuel as their main engines, but since 1961, the fleet is replenished, chiefly, with large-capacity fast vessels with modern power units. In 1961-70 average load-carrying capacity of vessels increased by 1.6 times and their speed increased by 25-30 percent (58 percent of the vessels will have a speed of over 18 knots), their average age was reduced (88 percent of the vessels will be up to 10 years old), their load characteristics and distribution by the types of the main engines were improved. The improvement of technical indexes will make it possible to reduce the length of docking in ports, to increase the carrying capacity of the vessels, to increase the labor productivity of the cruise, and to lower the proportional capital investments and the cargo transportation cost.

20

General-Purpose Dry-Cargo Vessels. In 1960, one half of the tonnage of this type of fleet consisted of vessels with deadweight of 9,000-10,000 tons, and the remaining tonnage was distributed approximately evenly among the groups of vessels with deadweight up to 2,200-4,000, 4,000-6,000, and 6,000-9,000 tons. Vessels built during prewar and war years constituted 60 percent of the tonnage, and half of it were vessels of nonseries construction. The vessels of the fleet had predominantly steam engines, some of which worked on solid fuel. The most characteristic representatives in individual tonnage groups were motorships of the "Tissa" type (deadweight 1,135 tons, speed of 9.2 knots), steamships of the "Kolomna" type (deadweight 4,410 tons, speed of 13 knots) and of the "Ivan Polzunov" type (deadweight 10,970 tons, speed of 12 knots).

Since 1961, the qualitative composition and structure of new general-purpose vessels changed sharply. In 1956-1960, vessels with deadweight from 9,000 tons and more constituted 25 percent of the tonnage built during those years, but in 1961-1970, the number of vessels of this group increased to 80 percent. As a result, in 1970, vessels with deadweight of 9,000 tons and more will constitute about 70 percent of the tonnage, and 20 percent of the tonnage will be vessels with deadweight of over 14,000 tons.

In 1961-1970, the technical and operational characteristics of vessels of each tonnage group were steadily improving. For example, until 1961 in the group of vessels with deadweight of 4,000-6,000 tons, the main type of vessels were steamships of the "Kolomna" type. In 1961-1970, this tonnage group was replenished with motor ships of the "Povenets", "Pioner", and other types. Instead of steam engines, vessels of these types have internal combustion engines, they have a higher speed (13.7 knots) and better load characteristics. This ensured the lowering of calculated proportinate expenses by 38 percent, the growth of the labor productivity of the crews by 17 percent and an increase of the average speed of vessels of the 4,000-6,000 tonnage group by 1.7 knots.

In the tonnage group of vessels with deadweight of 9,000 tons and more, the main type of vessels were steamships of the "Ivan Polzunov" type. In 1970, this group will consist, chiefly, of vessels of the types of "Bezhitsa," "Murom", "Slavyansk", "Krasnograd", and "Vyborg" with deadweight of 12,000-12,900 tons and speed of 17-18 knots, whose operation, in comparison with vessels of the "Ivan Polzunov" type, ensures the lowering of adjusted proportional expenses by 30-35 percent, increase of the labor productivity of the crew by 60 percent, and a considerable reduction in the docking time at ports (the group of the vessel for standardizing the intensity of loading operations increases from the fourth to the seventh-eighths).

Lumber Carriers. In 1960, the lumber-carrying fleet had few vessels. It consisted of outdated vessels, and 75 percent of its tonnage were vessels with deadweight of up to 4,000 tons. Since 1961, the fleet was replenished with vessels of large-series production whose deadweight was about 3,500 and 6,000 tons. These vessels constituted 72 and 27 percent, respectively, of

21

the entire replenishment tonnage of the lumber-carrying fleet. Due to this, it increased by 6 times by 1970 in comparison with 1960, and by 1971 it will consist only of standard large-series vessels. Although it will have vessels of all the necessary standard sizes, but 45 percent of the total tonnage will be lumber carriers with deadweights over 4,000 tons.

In 1961-1970, the technical and operational characteristics of lumber carriers of all tonnage groups improved. In 1960, the main type of lumber carriers were steamships with boilers working on coal of the "Khasan" type (deadweight 3,145 tons, speed of 10.3 knots), but, since 1961, average-tonnage lumber carriers were put into operation, such as vessels of the types of the "Kotlasles", "Maloyaroslavets", "Igarkales", and "Aleksandr Dovzhenko", and large-capacity vessels of the types of the "Volgoles" and "Vytegrales" with modern diesel engines and a speed of 13-15 knots. The use of these lumber carriers instead of the "Khasan" type vessels makes it possible to lower the adjusted proportionate expenses by 20-50 percent and to increase labor productivity of the crews by 30-60 percent.

Lumber carriers built in recent years are not at all inferior to foreign-built vessels in their technical and operational characteristics.

Bulk Carriers. In 1960, the specialized fleet for carrying bulk cargoes consisted of slow-going steamships of low load-carrying capacity with boilers operating on coal. For example, a greater percentage of the total tonnage was represented by outdated steamships of the "Pervomaysk" and "Chulym" types who had, respectively, the deadweight of 2,540-3,110 tons and speeds of 10.2 and 11.5 knots. In 1961-1965, and particularly since 1966, larger and faster bulk carriers were built of the types of the "Ugleural'sk" (deadweight 7,185 tons, speed of 15.5 knots),"Dzhankoy" (deadweight 9,750 tons, speed of 15.3 knots), and "Zvenigorod" (deadweight 23,000 tons, speed 15.5 knots).

As a result, the structure of the fleet for transporting bulk cargoes with respect to tonnage changes sharply: in 1970, the percentage of vessels with deadweights up to 5,000 tons will decrease to 42 percent, and for vessels with deadweights of 7,000-10,000 and 23,000 tons, it will be 32 and 26 percent respectively. More than one half of the tonnage will consist of motor ships well equipped for loading operations. For example, with respect to the standardization of the loading operations intensity, bulk carriers of the "Dzhankoy" and "Zvenigorod" type belong to the seventh group, and those of the "Pervomaysk" type belong to the fifth group.

Tankers. In 1960, the oil tanker fleet consisted, chiefly, of motorships of the "Kazbek" type (deadweight 11,700 tons and speed of 2.6 knots). In addition to them, an important place in the fleet was occupied by shallow-draft tankers of the "Oleg Koshevoy" type (deadweight 4,718 tons, speed 11 knots).

In 1961-1965, along with the continued construction of the "Kazbek" and "Oleg Koshevoy" type vessels, the fleet started to be replenished with

tankers of higher load-carrying capacities of the types of the "Bausk" (deadweight 18,190 tons), "Praga" (deadweight 30,900 tons), "Lisichansk" (deadweight 34,640 tons), and "Sofiya" (deadweight 49,370 tons). Vessels of these types have modern power units, and their speeds are from 15.6 to 18.7 knots.

The tendency of replenishing the oil tanker fleet, chiefly, with large series of high-capacity tankers still continues in the present five-year plan. During this period, the total replenishment tonnage of the fleet will include only 10 percent of vessels with less than 5,000 ton capacity, and vessels of 15,000-20,000 and 45,000 ton capacity will constitute 60 and 30 percent, respectively.

As a result of this, in 1970, 95 percent of the tonnage of the oil tanker fleet will be series-built tankers, and vessels with a carrying capacity of 35,000-50,000 tons will constitute approximately one half of the tonnage, while 20 percent will be tankers of 18,000-32,000 tons. Tankers of 10,000-16,000 ton capacity will also constitute about 20 percent of the tonnage: only 10 percent of the fleet will be tankers of lower capacities.

Analysis of the development of the oil tanker fleet in 1961-1970 shows a steady improvement in the technical and operational characteristics of tankers in all tonnage groups. The replenishment of the fleet with modern tankers with a higher cargo-carrying capacity ensures an increase in their speed by 17-30 percent, increase in the labor productivity of the crews by 20-60 percent, and a decrease in the adjusted proportionate expenses by 20-30 percent.

Special-Purpose Vessels. In 1961-1970, definite progress was made in developing special-purpose vessels. At the present time, icebreaker-transportation vessels of a new type have been put into operation for transporting dry cargoes into arctic ports, as well as gas carriers for transporting condensed gases, ferries for carrying railroad cars on the Baku-Krasnovodsk line, and refrigerator vessels.

Due to the high pace of the renewal of the fleet during the last decade and a considerable technical progress in the development of vessels for all purposes and individual tonnage groups, considerable obsolescence of vessels of some types can be expected.

The main principles of the method for calculating the replacement value of obsolete vessels are explained in work [6], where formulas are proposed for determining the replacement value of vessels of outdated designs:

$$B_y = \frac{B_r(D_y - R_y)}{D_r + a_{\text{н}}B_r - R_r},$$ (6)

where B_y is the replacement value of the outdated vessel;

B_r is the replacement value of vessels of the price-forming group;

D_y is the income from operating the outdated vessel;

R_y is the part of operational expenses of the outdated vessel which does not depend on its evaluation;

D_r is the income from operating vessels of the price-forming group;

a_H is the amortization norm for complete restoration;

R_r is the expenses on the operation of vessels of the price-forming group.

Computations by this formula will be very labor-consuming, will require collection, systemization and analysis of a vast amount of economic and statistical materials, and, therefore, can be done only after developing mathematical methods of analysis which would make it possible to use modern electronic computers. Great and sometimes insurmountable difficulties can be encountered in preparing initial data, because some necessary data on the fleets of capitalist countries are either not published at all, or are published occasionally and are incomplete. Moreover, cost indexes for merchant fleets of individual countries are expressed in different currencies, and their values are distorted by direct and hidden subsidizing. Therefore, at the present time it is impossible to use this formula directly.

Meanwhile, in order to solve the problems of the revaluation of the fleet, it is necessary, at the present time, to give practically acceptable methods for determining the replacement value of outdated vessels. In this connection, it is necessary to find simplified computation methods which would satisfy practical needs at the present time. However, such simplification must not lower the correctness of the results. This can be achieved if we limit ourselves to the economic data only on the domestic fleet, but use special methods for calculating the seven indexes included in the formula. These methods, briefly, consist in the following:

indexes for groups of vessels are replaced by indexes of a standard vessel;

the best vessels with respect to their technical and operational characteristics are selected as standard vessels among the vessels of the fleet (standard vessels can be not only domestically built, but also imported vessels).

Income from operating standard vessels is calculated by the following formula:

$$D_\vartheta = eB_\vartheta + R_\vartheta, \qquad (7)$$

where D_ϑ is income from operating the standard vessel;

e is the efficiency coefficient (assumed to be equal for all standard vessels);

B_ϑ is the replacement value of the standard vessel;

R_ϑ are operating expenses of the standard vessel.

Income from operating an outdated vessel are calculated by the formula

$$D_y = \frac{D_\vartheta}{P_\vartheta} P_y, \qquad (8)$$

24

where $P_\mathfrak{s}$ and P_y represent the carrying capacity in a unit of time of the standard vessel and the outdated vessel, respectively.

With allowance made for the simplifications, the formula for the evaluation of the outdated vessel with consideration for its obsolescence assumes the following form:

$$B_y = \frac{P_{\dot y}(eB_\mathfrak{s} + R_\mathfrak{s}) - R_y P_\mathfrak{s}}{P_\mathfrak{s}(e + a_{\text{H}})}. \tag{9}$$

This formula reflects only the essence of the above-mentioned method. Peculiarities of the operation of individual types of vessels, which are determined, chiefly, by their purposes, will make it necessary to alter the formula and use special methods for computing the indexes contained in it.

BIBLIOGRAPHY

1. "Metodicheskiye ukazaniya po sostavleniyu tsennikov dlya pereotsenki mashin, oborudovaniya i transportnykh sredstv na 1 yanvarya 1972 g" [Instructions on Methods for Compiling Price Handbooks for Revaluation of Machines, Equipment, and Means of Transportation as of 1 January 1972], Moscow, Izd TsSU SSSR, 1969.

2. Novikov, O. A. "Problems of the Revaluation of the Fixed Capital of the Maritime Fleet," in TRUDY TsNIIMF [Transactions of the Scientific Research Institute of the Maritime Fleet], No 114, Leningrad, Transport, 1969.

3. Novikov, O. A. "Comparative Analysis of the Costs, Labor Consumption, and Length of Construction of Vessels in the USSR and Countries with Developed Shipbuilding Industry," TsNIIMF Technical Report, Leningrad, 1966.

4. Novikov, O. A. "Improvement of Price Formation for Products of Civil Shipbuilding Industry," TsNIIMF Technical Report, Leningrad, 1969.

5. "Preyskurant No 20-02" [Price Catalog No 20-02]. "Wholesale Prices on Sea-Going, Lake, and River Self-Propelled Vessels (with engines of 400 horsepower and more) and Non-Self-Propelled Vessels (with a carrying capacity of 1000 tons and more), Ship Gear, and Equipment. Part I. Sea-Going, Lake, and River Vessels," Moscow, Preyskurantgiz, 1967.

6. Novikov, O. A. "Fundamental Principles of the Method for Determining the Degree and Level of Obsolescence of Maritime Vessels of the Transportation Fleet," TRUDY TsNIIMF, No 56, Leningrad, Transport, 1964.

UDC 629.123.4/.5:656.61:65.012.2

WAYS OF IMPROVING THE METHODS OF SUBSTANTIATING THE PLANS FOR THE DEVELOP-
MENT OF THE MARITIME CARGO-CARRYING FLEET   pp 28-59

[Article by V. I. Krayev, Candidate of Economic Sciences]

The raising of the level of scientific substantiation of national economic
plans and plans of individual sectors of economy is achieved by steady ad-
herence to the basic principles of scientific planning. The most important
of them are the leading role of long-term plans, the combination of long-
term and current planning and their continuity, overall planning, and isola-
tion of the leading parts in the plans. Realization of these principles in
working out a plan for the development of the maritime transportation system
for 1971-1975 made it possible to determine the necessary levels of the de-
velopment of the material and technical resources of the maritime transpor-
tation system and to select the most effective solutions for developing its
individual elements with consideration for the high pace of the technologi-
cal progress.

Adherence to the fundamental principles of scientific planning made it pos-
sible to expand the substantiation of the draft of the plan, as a result ot
which:

a) the main levels of the development of the maritime transportation system
for 1971-1975 were coordinated with predictions for the development of this
sector of industry for 1980 and 2000, which, in turn, were coordinated with
the development of other types of transportation;

b) the development of individual elements of the material and technical re-
sources of the maritime transportation system was substantiated in an inte-
grated manner with consideration for the interaction of individual elements
both with respect to their technical aspects (combination of parameters),
and with respect to their economy level.

The transportation fleet, which is the basis of the functioning and the funds
of maritime transportation system, was taken to be the leading unit of the
material and technical resources. In working out the plan for the develop-
ment of this sector of industry, problems connected with the fleet are

26

separated into an independent division which gives scientific substantiation for future development of the fleet of the Ministry of the Maritime Fleet for basins and steamship lines.

Technical and economic studies in this division included the substantiation of the main parameters of freight traffic, structure and volume of the fleet in the future, determination of the write-off volume of the operating fleet, the necessary capital investments, and their effectiveness. In this research, stress was placed on the problems of substantiating the types of transportation vessels and the program for replenishing the fleet during the planned period.

The above-mentioned problems included a large group of problems which were solved on the basis of methods and norms stated in the theses of the Standard Methods of Determining Ecomonic Effectiveness of Capital Investments. However, the development of the main theses of the Standard Methods issued in 1969, methodology of prognostication and planning, improvement of the organization and methods of studies on economic effectiveness of new equipment in the national economy, the possibility of wide utilization of modern mathematical methods and computers, as well as the raising of the overall level of economic work in maritime transportation require a critical analysis of the basic methodological principles and a normalized basis for technical and economic substantiation, as well as the development of proposals for their improvement in order to increase the degree of scientific substantiation of the development plan for 1976-1980 and later.

The Content of Technical and Economic Substantiations of Long-Term Plans for the Development of the Material and Technical Resources of the Marine Transportation System

The development of the national economy imposes the following demands on the marine transportation system:

-- full satisfaction of the needs in sea shipping between economic regions of the country;

-- ensuring the country's independence in shipping foreign trade cargoes;

-- helping the countries of the socialist camp in achieving independence of their foreign trade shipping from the capitalist countries;

-- development of the shipping of cargoes of foreign charterers in order to activate the currency balance of the country.

Fulfillment of these requirements must be accompanied by raising the productivity of national labor and by lowering the expenses of the national economy on freight transportation. This is possible only with constant improvement of the material and technical resources of the maritime transportation system.

27

Consequently, the objective factor determining the development of the material and technical resources of the maritime transportation system is the need of the country's national economy in sea shipping of cargoes and in the inflow of foreign currencies, which, in turn, determine the necessary production capacity of the transportation fleet, the capacities of the ports, the needs for the auxiliary-service, ice-breaking, and technical fleets, and the capacities of ship repair yards.

The maritime transportation system differs substantially from other types of transportation because the fulfillment of the above-mentioned national economic requirement affects differently the pace of the development of individual elements of its material and technical resources. For example, in order to fulfill the volume of coastwise shipping of sea shipping, the maritime transportation system must have a fleet of a proper capacity, port installations, auxiliary service and technical fleet at the dispatch and destination points of the freight, and ship repair yards.

Exported and imported cargoes are transported by Soviet and foreign ships. Therefore, the capacity of the transportation fleet must not correspond to the entire volume of freight but only to that part which has to be performed by the Soviet fleet. The capacity of the fleet for transporting exported and imported freights must correspond to the capacity of the ship repair yards. The capacity of the ports and of the auxiliary and technical fleet must correspond to the volume of the dispatched exported cargoes and to the volume of the arriving imported cargoes. Finally, in order to accomplish the volume of shipping of the countries of the socialist camp planned for Soviet vessels and shipments of foreign charterers, it is only necessary to have a transportation fleet of an appropriate capacity and a ship repair yard.

Let us mention that foreign currencies can be received for various services to foreign vessels: for ice-breaking services along the Northern Sea Routes, sales of fuel, water and supplies, and repairs. However, the evaluation of the effectiveness of the development of the material and technical resources for these purposes can be solved independently.

Thus, the transportation fleet is the necessary element in solving any of the above-mentioned problems, and the capital investments into it constitute 60-70 percent of the total volume directed toward the development of the maritime transportation system. Therefore, the problems of the substantiation of the production capacity of the transportation fleet and its structure according to its purpose and types of vessels are given a central place in the scientific substantiation of the plans for the development of the maritime transportation system. As a result, the overall need in transportation vessels and the structure of the fleet according to kinds and types of vessels is established for the planned period. In the course of substantiating the overall needs in the fleet and its structure, it becomes necessary to evaluate the expediency of:

a) the use of the transportation fleet operating at the beginning of the planned period some of whose concrete types of vessels were discontinued:

b) the continuation of the construction of vessels of the shipbuilding program of the period preceding the planned period;

c) the designing and construction of new types of maritime transport vessels in the course of the planned period.

The volume and structure of the new additions to the fleet is determined on the basis of the established overall need in the tonnage, evaluation of the write-off volume of the operating fleet, and substantiation of the types of vessels whose construction will be economically effective during the planned period. Later, during the stage of the development of the shipbuilding program, optimal distribution of orders for the construction of the new field among concrete domestic and foreign shipyards is substantiated.

The interrelationship of the fleet and other production elements of the material and technical resources of the maritime transportation system determines the necessity of technical and economic studies for establishing qualitative and quantitative dependences on the characteristics of the vessels:

for ports -- the dimensions of approach channels, total water surface of harbor, characteristics of berths, types of loading equipment, number of operation lines, warehouse capacities, length of approach roads, capacity of stations;

for the auxiliary service fleet -- types and power of tugboats, bunkering crafts, waterboats, port icebreakers, etc;

for bunkering bases -- their capacity, amounts of fuel of various grades, equipment for its preparation, intensity of bunkering;

for ship-repair yards -- depths near docks, capacity of ship-raising equipment and cranes, capacities of repair shops and equipment.

Individual elements, such as ports, bunkering bases, and, to some extent, ship repair yards, are intended to serve not only Soviet, but also foreign vessels carrying foreign-trade cargoes of the USSR. This affects the selection of their optimal parameters through distribution of expenses between the Soviet and foreign fleets, as well as through the value of the transportation component in the price of the merchandise.

In substantiating the development of the Soviet fleet, the following should be taken into consideration: limitations with respect to overall dimensions, mechanization level, intensity of processing, bunkering and supply conditions of Soviet vessels in foreign ports, which in some instances play an important role.

With the integrated nature of substantiations for the development of the material and technical resources, these methods of studies and the standardization must ensure the necessary accuracy of the results, their comparability in time and with respect to individual elements, and their progressiveness. Insufficient consideration for these requirements can upset the proportions in the development of the material and technical resources of the maritime transportation system, lower the effectiveness of the utilization of its fixed capital, and, in some instances, can disturb the normal functioning of individual sectors of the national economy.

In recent years, research and designing organizations of the Ministry of the Maritime Fleet have established with sufficient details the nature of inter-relations of individual elements of the maritime transportation system, formalized partially their dependences, and developed basic standards. Individual problems are solved with electronic computers. At the same time, some problems of methods have not yet been worked out completely, some theses of their methods are declarative, and the basic standards need to be developed and made more precise because they are oriented toward the use of outdated computation methods with a limited number of variants of solutions.

The Degree of the Development of the Methods for Substantiating New Types of Vessels and Suggestions for Their Improvement

Not all problems which are included in the general solution of the problem of the substantiation of the plan for the development of the material and technical resources of the maritime transportation system are connected directly with the substantiation of the total need in the transportation fleet, selection of new type of vessels, and determination of the shipbuilding program. For example, the following problems are completely independent: complexes of methodological problems for the purpose of substantiating the volume, direction, and structure of sea shipping, and its zoning; problems of establishing the volume of freight turnover, specialization, production capacity, location, arrangement, and zoning of sea ports; problems of substantiating the capacity, specialization, and location of ship-repair yards, etc. The main points of the methods for solving these problems are explained in works [1,2] and are not discussed here.

General Methodological Approach

The general methodological approach to the substantiation of the need in cargo fleet, new types of vessels, and a construction program for the planned period is determined by the following main elements:

1) the structure of problems to be solved;

2) basis for the solution of problems;

3) sequence of solving the problems;

4) complexity level of the solution of problems;

5) estimated period of optimization.

The structure of problems to be solved in substantiating the development of the fleet for the planned period includes:

-- determination of the overall need in the tonnage;

-- determination of the write-off volume and the carry-over volume of the operating fleet;

-- selection of types of vessels to be built;

-- substantiation of the type characteristic (schedule for types) of vessels;

-- substantiation of the program for fleet replenishment;

-- determination of the shipbuilding program;

-- development of technical specifications for designing new types of vessels.

In recent years, methodological works usually indicate (or more frequently imply) all of the above-mentioned problems. However, the internal content of individual problems, for example, the substantiation of the schedule for types of vessels, is treated in different ways. For example, in the river transportation system [3], the schedule for the type of vessels is substantiated separately from other problems, and the types of vessels recommended in the schedule for series construction could be included in the shipbuild-ing programs of several adjacent planned periods. A different meaning is given to the concept of the "schedule for types of vessels" in substantiat-ing the replenishment programs of the maritime fleet. The purpose of the development of a schedule for the types of vessels (in some works called a "type-size system") is to establish the member of types (type characteristics) of vessels recommended for inclusion into the program of fleet replenishment and to define precisely their operational and technical characteristics. It is considered that the formation of the schedule for types of vessels is a necessary but not an independent problem of the shipbuilding program.

Such differences in the approach to the schedule for types of vessels de-veloped historically in the process of standardization of the means of water transportation. The technical complexity of maritime vessels, the dependence of their characteristics on the changing conditions of navigation, and the necessity of ensuring the competitiveness of the Soviet fleet in the world shipping made it necessary to give up the principle of stopping at many ports by freighters for long periods of time. However, the problem of the role of the schedule for types of vessels, its inner content, and principles of its substantiation has not yet been solved completely. In our opinion, the most accurate method of developing and substantiating parametric series of

31

maritime freighters is the method whose principles are explained in work [7]. Studies in this direction must be continued.

Solution of the above-mentioned problems will make it possible to develop a scientifically substantiated draft of a plan for developing the transportation fleet whose basic results will determine the tonnage needs and structure, as well as the shipbuilding program and technical specification for designing new types of vessels. It should be mentioned that the general statement of the problem was not formulated sufficiently accurately in most of the methodological works [1,9-13], because they stressed intermediate problems (in relation to the main problem) of substantiating the programs for fleet replenishment and new types of vessels, but not the substantiation of the general need in the tonnage and its structure.

As a result, the solution of such intermediate problems included, as a condition, the solution of the main problem of the substantiation of needs in the fleet and another intermediate problem -- evaluation of the carry-over volume of the operating fleet.

At the same time, let us note that some works [1, 11, 12] erroneously identified the program of fleet replenishment (i.e., the number of vessels of concrete types) with the shipbuilding program (distribution of a number of vessels of each type by shipyards (countries) and by years of delivery).

On the basis of the above, scientific substantiation of the plan for the development of the transportation fleet must include the solution of the following problems:

main problem -- determination of the need in vessels;

intermediate problems -- determination of the carry-over volume of the operating fleet; substantiation of the types of vessels to be built; substantiation of the program for fleet replenishment supplemented by a schedule for types of vessels; substantiation of the shipbuilding program; development of technical specifications for designing new types of vessels.

The objective basis for the substantiation of the plan for the development of the cargo fleet is the planned volume of the transportation work on shipping cargoes. The total volume of transportation work is differentiated by the types of shipping, freights, directions and is supplemented by the data on the type of freight, seasonal characteristics, and size of shipments.

Without disagreeing that objectively of planned freight traffic is a basis for working out a plan for the development of the fleet, a number of reseachers have expressed doubts that the results of the substantiation of the type of vessels planned for the replenishment of the fleet during the period of the plan on the basis of planned freight traffic is optimal [3]. In the opinion of the author of work [13], such doubt is based on insufficient accuracy in the determination of the structure and directions of a considerable part of foreign trade shipments. Viewing the "general methodology of

solving ... the technical and economic substantiation of the shipbuilding program" as a combination of special methods for solving three main problems (development of a "type-size system" of vessels for the replenishment of the fleet, determination of optimal parameters of standard vessels and determination of the need in the replenishment of the fleet with optimal standard vessels), the author proposes "... to recognize the objective expediency of the division of the general-purpose fleet into groups which developed spontaneously in the world shipping" for developing a "type-size system" for the vessels of the domestic fleet. In our opinion, this proposal is wrong because of the following reasons:

a) in their total mass, the structure and directions of foreign trade shipments of the USSR are sufficiently stable, and the correctness of planned freight traffic increases during the last stages of the development of the plan;

b) the spontaneously formed groups of the world fleet can only in some instances correspond to the concrete conditions of the Soviet foreign trade transport operations;

c) the reference to the disparity between the stability of the initial planned freight traffic and the longevity of vessels substantiated by it only stresses the impossibility of the optimization of the "type-size system" for new vessels to be added to the Soviet fleet on the basis of average statistical data for the world fleet which reflect the conditions of the world shipping during the past periods of indefinite lengths;

d) averaged data on the world freight traffic excludes the possibility of substantiating the specialization of the fleet.

At the same time, it cannot be denied that analysis of the composition of the replenishment of the world fleet with division by countries, directions of service, and years of construction is one of the necessary factors that are taken into consideration during the preliminary stage of substantiating planned variants of vessels for the replenishment of the domestic fleet in evaluating the results of the substantiation of the replenishment program.

Thus, the basis for the substantiation of the plan for the development of the transportation fleet should be the planned volume of the transportation work with the necessary differentiation by directions, structure, type of transportation, seasonal characteristics, and the size of shipments. If mathematical methods and electronic computers are used, it is necessary to evaluate the stability of results depending on the stability of the future freight traffic.

Examining the problem of the sequence of substantiating the plan for the development of the transportation fleet, we should subdivide the existing methods into two groups.

The first group includes methods oriented toward manual computations. The basic principles of their method were developed at the end of the fifties and the beginning of the sixties and were based on practice and norms which formed by that time. All problems developed in the process of the substantiation of the plan for the development of the transportation fleet were solved separately. The results of the solutions of individual intermediate problems (substantiation of new type vessels, write-off volume and fleet replenishment volume) were taken as a fixed optimal basis for solving other intermediate problems or the main problem. The most methodologically developed problems (as intermediate problems without their interrelation with others) are the problems of selecting the characteristics of vessels for individual directions of shipping and substantiating the program for fleet replenishment [6 and 14]. The works specified several consecutive stages, and the accuracy of the initial basis increased at each subsequent stage. However, the content of the studies and the requirements for the accuracy of the initial bases at various stages were not substantiated. Methods for evaluating the needs in the fleet and the effectiveness of the utilization of operating vessels in combination with new ones have not yet been sufficiently studied and are based on the statistical report data and standardization documents. As a result, a wide use is made of the method of evaluations by experts, which does not exclude subjective approach and considerable errors. Methods for optimizing the shipbuilding program have not been developed at all.

The second group includes methods oriented toward the use of electronic computers. This method makes it possible to increase considerably the number of solutions, as well as to allow for the interaction of the results of solutions of special individual problems. In work [9], linear programming methods were used for solving a general problem of determining the optimal need in the transportation fleet on the basis of simultaneous solution of intermediate problems of selecting the types of new vessels, effectiveness of the utilization of the carry-over volume of the operating fleet and determination of the program for replenishing the new fleet. For the first time an attempt was made to remove the main deficiencies of the methods intended for manual computations -- to solve simultaneously the problems of selecting the types of new vessels and the number of vessels of each type, and to allow for the influence of the vessels of the operating fleet on the selection of optimal characteristics for the new types of vessels and their number. In principle, the suggested method allowed for solving the general problem by several subsequent approximations (stages) differing in the groups of expenses, accuracy of the initial bases and the number of unknown parameters.

Theoretical and practical experience accumulated in the process of the utilization of the above-mentioned method was used in work [17]. Along with using more perfect mathematical devices (nonlinear and stochastic programming, methods for evaluating the stability and correction of results, etc), the problem of calculating the effect of series construction on the effectiveness of the utilization of the vessel was solved. Just as in work [9], this method makes it possible, in principle, to solve this problem in several stages.

At the same time, having made provisions for solving a problem in a general form, the authors did not concretize the intermediate problems and the differentiation of the general problem at various stages. As a result, due to a considerable number of assumptions and approximations, the answer satisfies only the requirements of the stage of working out preliminary proposals for the plan for the development of the transportation fleet.

A clearer formulation was given for the necessity of multistage solutions of problems in application to the substantiation of the program for replenishing the transportation fleet and selecting types of vessels by mathematical methods in works [1, 11, 12]. There are two stages:

the first stage -- optimal "technical" characteristics and the number of new-type vessels corresponding to them are determined for each shipping direction and for a fixed series construction;

the second stage -- the effectiveness of the standardization and specialization of vessels is compared (i.e., the replenishment program is optimized with consideration for the effect of series construction).

Having determined correctly the necessity of substantiating only a limited group of the most important characteristics of vessels during the first stages, the authors of these works did not formulate correctly the stages of the solution of the general problem, having made it dependent on the factors of the series construction of vessels. A method for computing this factor was used later (regardless of the stage) in work [14]. Apart from this, works [1,11,15] had proposals for general recommendations on the sequence of solving problems of evaluating the effectiveness of the utilization of the operating fleet and new additions to the fleet, to which, in principle, there are no objections, but they need to be made more concrete and detailed.

Thus, the following conclusions can be made:

-- so far, there is no clear solution for the problem of stages in the substantiation of the plan for the development of the transportation fleet; the purpose of each stage and the group of problems solved simultaneously in each stage have not been formulated;

-- the degree of the necessary and expedient accuracy in solving problems has not been differentiated depending on the calculated expenses, accuracy of the initial basis, and the possibility of using approximation methods;

-- no substantiation has been given for the number of parameters sought at various stages which are necessary for solving the general problem and determining the interrelation of other elements of the material and technical resources of the maritime transportation system with the fleet.

On the basis of the experience in substantiating the plan for the development of the transportation fleet, the interdependence of the parameters of vessels

and other elements of the material and technical resources of the maritime transportation system and the possibilities of optimization with the use of mathemetical methods and electronic computers, the following approximate sequence of the substantiation of the plan for the development of the transportation fleet is proposed.

Stage I -- substantiation of the main directions in the development of the transportation fleet for the planned period. The goal is: to establish the preliminary prediction of the total need in the transportation fleet and its structure according to its types; the overall development and structure of the carry-over fleet; the total volume and structure of the replenishment by the fleet types, the types of vessels, and their number (supplement -- the type characteristics of new vessels). Direct expenses on the transportation fleet are taken into consideration. New vessels are differentiated by their purpose, carrying capacity, and speed (characteristics determining their carrying capacity). General exaggerated dependence of direct costs on the variant series of main characteristics of the vessel is used.

Stage II -- substantiation of the plan for the development of the transportation fleet for the planned period. The goal is to establish the general need and structure of the tonnage for the planned period, the overall volume and structure of the tonnage used at the beginning of the planned period, the overall volume and structure of the replenishment by the types of vessels and their number (supplement -- schedule for types of vessels), and operational and economic indexes for the old and new fleets. Direct expenses on the transportation fleet and accompanying expenses on other elements of the maritime transportation system are taken into consideration. A limitation on capital investments is introduced. New vessels are differentiated with respect to their purpose, carrying capacity, speed, architectural design type, automation level, and the types of their power units. Detailed dependences of direct and accompanying costs on the varient series of vessel characteristics developed on the basis of the results of preliminary proposals are used.

Stage III -- finer definition of the plan for the development of the transportation fleet for the planned period. The goal is to define more accurately the results of solving the problems done at Stage II. Direct fleet costs accompanying   other elements of the maritime transportation system and conjugated expenses in other sectors of economy are computed. Limitations of capital investments are defined more accurately. The purpose, carrying capacity, and speed of new vessels are differentiated within limits close to optimal as established during Stage II. The dependences of direct, accompanying, and conjugated expenses on the varients of vessel characteristics defined more accurately by the results of Stage II are used.

Simultaneously, but with consideration for the result of Stage II, technical specifications are developed and substantiated for new types of vessels or for the modernization of the designs of vessels under construction.

Integrated way of solving the problem of substantiating the plan for the development of the transportation fleet must be reviewed as simultaneous solution of main and special problems (overall solution or part by part), as well as the possibility and necessity of calculating the accompanying and associated expenses.

Being based on the general needs of the national economy in the maritime transportation fleet, the total volume of the transportation work during the planned period consists of transporting cargoes coastwise, transporting export and import goods, and transporting cargoes of foreign charterers. The transportation of freight is distributed by basins and is done by various types of fleet. Therefore, for each main problem (carry-over volume of the operating fleet, new types of vessels, program for fleet replenishment, shipbuilding program), it is necessary to consider the expediency of its solution either part by part, or simultaneously for all types of freight transportation, types of fleet, and basins.

Types of Freight Transportation. The economic nature of coastwise and export-import freight transportation is to satisfy the need of the national economy in moving masses of goods at the lowest cost to the national economy. This determines the necessity of simultaneous substantiation of the plan for the development of the transportation fleet. The development of this shipping makes it necessary to develop all elements of the material and technical resources of the maritime transportation system of the country. In principle, any vessel of the operating fleet or one scheduled for construction can be used for export-import and coastwise shipping, if its operation ensures a sufficient effectiveness of capital investments which are necessary for handling the entire volume of export-import and coastwise shipping.

The economic nature of the shipping of cargoes of foreign charterers (CFC) is different. The growth of this shipping requires the development of only some elements of the domestic maritime transportation system. The requirements for vessels carrying CFC are determined by the operation conditions along international routes, which, in many instances, can be quite different from the conditions of coastwise and export-import routes. Moreover, vessels for CFC shipping must be competitive in this sphere of world navigation.

This division of the problem of evaluating the overall need in the fleet was accepted for substantiating the development plan for 1971-1975. An analogous solution is also recommended in work [12].

The authors of work [14] propose a different solution: they recommend to substantiate new types of vessels and programs for fleet replenishment for the maritime transportation system as a whole without separating CFC shipping. This recommendation makes it necessary for the authors to introduce age limitations for vessels handling CFC shipments (only vessels built in the future), as well as predetermines the relative nature of the accepted efficiency criterion.

37

Thus, there is no single opinion about the expediency of solving the problem of substantiating the plan for the development of the transportation fleet as a whole or part by part.

It appears more justifiable to divide the main problem into two special problems: the first problem is for export-import and coastwise shipping, and the second for CFC shipping. However, it is still unclear how to approach the substantiation of the CFC shipping performed under the conditions of a time charter.

Studies and the solution of this problem in the process of the development of a mathematical model are most urgent.

Types of Fleet. At the present time, there is a single opinion about the division of the main problems on the substantiation of the development of the transportation fleet into special problems for the passenger, tanker, dry-cargo, and very specialized fleets. The expediency of this division does not cause any doubts beacuse it simplifies the solution considerably, and the utilization of such vessel types for purposes which are not characteristic of them occurs more rarely with the development of the Soviet fleet. Therefore, this can be disregarded in evaluating the future development of the fleet. At the same time, it is necessary to develop in detail and substantiate the classification of the fleet for general purpose and specialized vessels. There is no doubt that gas carriers, chemicals carriers, ferries, trailer carriers, and lighter carriers must be separated into a group of very specialized vessels, but it is not clear how to classify large bulk carriers, medium-size tankers, lumber carriers, etc.

At the same time, it is also necessary to examine the problem of substantiating dry-cargo vessels for serving regular routes. Due to specific conditions of operation and structure of freight traffic along regular routes, there arises the question of the possibility of isolating a special problem of substantiating the types and number of vessels for them. However, it is necessary to consider the possibility of using identical vessels for international and export-import routes, which makes the evaluation of series of construction of vessels of individual types indefinite. This problem must be developed as soon as possible in application to various stages of the substantiation of the fleet development plan.

Marine Basins. At the present time, there is no sufficiently substantiated opinion about the devision of the main problem into special problems by marine basins. At various stages of the substantiation of the plan, individual problems are solved in application to individual concrete directions of shipping, groups of directions, by basins, or for the maritime fleet as a whole. The reasons for this situation were the potentialities and methods of economic substantiations with the use of manual computations.

Various solutions have been recommended in works with the application of mathematical methods. For example, in the earliest work [9], it was proposed to isolate individual basins and groups of routes with specific

conditions; later, in works [12,14] -- to perform computations for the maritime fleet as a whole. In work [12], this proposal is explained by the necessity of determining optimal distribution of the old and new fleet among the basins simultaneously with substantiating types of new vessels, the program of fleet replenishment, and the carry-over volume of the operating fleet. This proposal appears to be well justified, however, it is possible to exclude the fleet of the Caspian basin, because its bulk is adapted to the specific conditions of operation. Moreover, it is necessary to compare the effects of the consolidation or detailization of the planned routes of shipping in solving problems for the fleet as a whole or by the basins; the necessity of such comparison is dictated by a large number of concrete similarities of cargoes for the planned period and limited potentialities of electronic computers.

The Possibility of Estimating Accompanying and Associated Expenses. In all methodological works of recent years, it was recognized that, in substantiating types of vessels, the replenishment program and the overall need in the fleet, it is necessary to estimate not only direct expenses on the fleet, but also expenses on other elements of the material and technical resources of the maritime transportation system, and even on other branches of the national economy.

In work [8], it was recommended to take into consideration the accompanying investments into ports when substantiating the carrying capacities and types of architectural designs of vessels, the working capital in cargoes -- when substantiating the speed and the carrying capacity of vessels, and expenses of the fuel industry -- when selecting the type of power units. Later, in the process of practical realization of developed theses, it was recognized that the total influence of accompanying and associated expenses should be taken into consideration during the stage of substantiation of the fleet replenishment program, but, in substantiating the types of vessels, it is necessary to consider them only when selecting very specialized vessels which require considerable expenses on shore installations (gas carriers, container carriers, ferries, etc), as well as large capacity vessels which are considerably larger than the vessels of the operating fleet [7].

In works [9,14], the problems of estimating associated and accompanying expenses were not examined.

The most extensive recommendations on accompanying and associated expenses in application to the problems of substantiating types of vessels and the fleet replenishment program are contained in works [1, 12, 15]. The authors recommended to substantiate types of vessels and the replenishment program, first, only with consideration of direct expenses on the fleet, accompanying expenses for ship repair yards, and associated expenses in the fuel industry. On the basis of the obtained data for the fleet and ports, economic effectiveness of using large-capacity vessels is estimated with consideration for the accompanying expenses in the ports. Series construction of vessels is not taken into consideration. This proposal is contradictory in nature, because

the determination of the volume of expenses on ship repair yards and ports without consideration for series construction of vessels can result in gross errors, and the estimation of port expenses exclusively on the basis of preliminarily selected and adjacent variants of large-capacity vessels will even increase these errors. It is also doubtful that it is necessary to consider associated expenses in the fuel industry, particularly during the first stages of the substantiation of the fleet development plan, when, due to the absence of detailed substantiated relationships, general dependences of economic characteristics of vessels and other elements on their parameters are used.

Thus, at the present time, there is a sufficiently substantiated method of estimating the working capital in cargoes for substantiating types of vessels and individual proposals for estimating associated and accompanying expenses for the substantiation of the fleet development plan. The existing proposals must be developed and refined further with consideration for the degree of the influence of comparative effectiveness of variants, establishment of numerical relationship, a list of expenses and detailization during various stages on the results.

Periods for Calculating Optimization. Long-range plans of the national economy and plans for developing the maritime transportation system are substantiated most frequently for five years, and less frequently for 10 years and more. However, in any case, a long-range plan covers a period of several years.

The substantiation of the plan for the development of the transportation fleet has always been done in application to the final year of a planned period.

The need in the fleet, types of vessels, carry-over volume, and the replenishment program were determined from the condition of the full satisfaction of shipping needs during the final year, i.e., the solution was optimal only for the conditions of some strictly fixed space of time in the planned period.

However, the increase in the volume of the transportation work may be uneven in different years. Moreover, the capacity of the shipbuilding industry will, of course, be increasing unevenly. Consequently, a long-range plan will be optimal only if the conditions of its optimalness will be considered not only in application to the static level of a definite term of calculations, but also in the dynamics of their changes during the entire planned period. This condition of optimization in application to the problem of the substantiation of the program for the replenishment of the maritime fleet was stated for the first time in work [14]. However, this dynamic problem was stated in a very general form.

On the other hand, the solving of the problem of optimizing the development of the fleet by the indexes for the entire period of the plan presents definite difficulties both with respect to methods and in the preparation of

the initial basis. Moreover, such solving does not remove a more important contradiction between the dynamic nature of the development of the system (of maritime transportation) and the static method of solving, because the service life of maritime vessels is considerably longer than the periods of the plans. Therefore, it appears more correct to solve this problem in application to several calculation years, for example, the last years of several successive five-year periods. The number of calculation years may be taken to be equal to three or four, which corresponds to a calendar period of 15 or 20 years. For such a period, it is possible to make sufficiently accurate predictions of the technical progress in the shipbuilding industry, volumes of cargo traffic and methods of transportation, conditions of fleet operations, etc. The optimalness of the solution of problems by this method will be substantiated better than a solution for a single plan period. However, there arises the problem of methods for calculating the differences in the degrees of accuracy of the entire initial basis for various computation years which are removed by 7-8, 12-13, 17-18, and 22-23 years from the moment of solving. This is a complicated problem, but it must be studied and solved in the near future because it will determine the form of the mathematical model.

Optimalness Criteria and Indexes of Effectiveness

Selection of the indexes of economic effectiveness has been given considerable attention in all methodological works of recent years. Several proposals are explained below.

In works [6, 8], it was recommended to use the index of normalized expenses for coastwise shipping and normalized currency expences for vessels on foreign routes as the main index for evaluating the comparative effectiveness of the variants of new types of vessels. An index of normalized expenses for vessels of coastwise and foreign routes was used in work [9]. The principle of minimizing current and capital expenses of the fleet was also used in a number of interrelated works of the Soyuzmorniiproyekt [State Planning, Design and Scientific Research Institute of Marine Transportation of the Ministry of the Maritime Fleet, USSR] [13, 16]. However, there were also other proposals. For example, the index (criterion) of effectiveness was differentiated in works [11, 15]:

for coastwise shipping -- minimum of normalized expenses;

for export-import shipping -- maximum of foreign currency proceeds per one ruble of capital investments;

for CFC shipping -- minimum of normalized expenses per one ruble for foreign currency proceeds.

This differentiation of the main index, naturally, predetermined a differentiated solution of the optimization problem of fleet development, with which we cannot agree. In the later work, the authors themselves proposed a

41

system of main and additional indexes for evaluating the effectiveness of capital investments into the utilization of the fleet [11].

The same authors [1, 12] proposed to return to the index of normalized expenses for evaluating the effectiveness of various types of vessels and the replenishment program for the fleet for coastwise and export-import shipping and to the index of normalized currency expenses for the CFC shipping.

Work [14], on the basis of the requirement of having a single criterion for the fleet as a whole, regardless of the sphere of its utilization (coastwise or foreign shipping), proposed to accept the criterion of the minimum of normalized expenses on the fleet per one ruble of not foreign currency proceeds. Here, the expenditure part of the index includes expenses on the fleet developing both coastwise and foreign shipping, and its income part includes only the receipts from the operation of the fleet on routes to foreign countries. In order to eliminate this defect, it was suggested to include "conventional losses of forcing currency proceeds from diverting the fleet to coastwise shipping from routes to foreign countries." The artificiality of this method is obvious.

Consequently, to date there is no generally accepted criterion for solving optimization problems in evaluating the economic effectiveness in evaluating the economic effectiveness of the development of the transportation fleet. Earlier proposals were recommendations without sufficient substantiation. Considering the importance of the effectiveness criterion for optimization problems, let us examine this problem in more detail.

In our opinion, in selecting the effectiveness criterion for such a large complex problem as the substantiation of the plan for the development of the transportation fleet, it is necessary to consider the requirements for ensuring the uniqueness of the results in solving the main problem (substantiation of economic effectiveness of the entire transportation fleet) and intermediate or special problems (selection of types of vessels, the fleet replenishment program, carry-over volume of the old fleet, for various types of navigation, various types of fleet, etc). Consequently, the effectiveness criterion must be the same, which, however, does not exclude the necessity and possibility of using various additional indexes for evaluating the results of special and intermediate problems.

Another very important requirement is the necessity of considering the specific characteristics of the marine transportation system as a production sector. The production of the maritime fleet is the transportation of cargoes and passengers, conditions of transportation, as well as its "quality" (for example, comfortable conditions of passenger transportation, speed of delivering cargoes and passengers), which can differ considerably. These factors are (or must be) reflected in the cost of transportation, i.e., in the rates and freight fees.

Consequently, the effectiveness criterion must allow for the changes not only in the expenses, but also in the receipts.

Methods for substantiating the economic effectiveness of the level and nature of the material and technical resources of the maritime transportation system must be based on common principles for evaluating the effectiveness of capital investments and new technology in the national economy. It is recommended to use standard methods for determining economic effectiveness of capital investments [17] at all stages of the development of yearly and five-year plans, as well as plans for later periods for the national economy and its branches, and in developing individual technical and economic problems in determining the overall economic effectiveness of capital investments. In application to the problem of substantiating the plan for the development of the maritime transportation fleet, the index of the overall economic effectiveness of capital investments is the ratio of the increment of the annual profit in the planned period $\Delta \Pi$ to the capital investments into the construction of objects for production purposes K which brought about this increment:

$$\vartheta = \frac{\Delta \Pi}{K}.$$

However, the main condition for a correct solution of the optimization problem of substantiating the plan for the development of the transportation fleet is the necessity of including vessels of the old fleet (operating at the beginning of the planned period) in it. With this condition, it is possible to determine the total amount of income for the entire volume of shipping, the total amount of expenditures for the entire transportation fleet and investments into other elements of the fixed productive capital of the maritime transportation system or connected branches of economy which may vary. The maximum profit for the entire transportation fleet (with limited capital investments during the planned period) or the maximum level of profit per ruble of capital investments (with unlimited capital investments) will determine the optimal variant of the plan for the development of the transportation fleet.

Thus, it is recommended to use the ratio of the difference of the total income from the utilization of the transportation fleet ΣD_ϕ and total expenditures ΣR_ϕ on it with consideration for dependent expenses ΣR_3 to new capital investments $K_{\text{н},\phi}$ as a criterion for selecting the optimal varient of the plan for the development of the transportation fleet.

$$\vartheta = \frac{\Sigma D_\phi - (\Sigma R_\phi + \Sigma R_3)}{K_{\text{н}.\,\phi}}.$$

When this criterion is used, it is necessary to express the Soviet and foreign currencies in terms of comparable values, which is possible by using coefficients. The values of the coefficients in application to the problem of the optimization of the plan for the development of the material and technical resources of the maritime transportation system must be substantiated additionally.

In solving various problems of the optimization of the plan for the development of the transportation fleet apart from direct expenditures (current and one time expenses) on the transportation fleet proper, expenses on ports,

shipyards and other types of fleets whose parameters are connected with the characteristics of the vessels (level of specialization, carrying capacity, type of architectural design, type of power units) will change depending on the computation variants. For example, the specialization of a vessel determines the following: the method of reloading; the type, equipment, and the capacity of the berth; the type, size, and handling capacity of the warehouses; expenses on special equipment. This carrying capacity of a vessel determines: the dimensions of the approach channels and water area of the port; the parameters and the capacity of the berths and warehouses; the number of approach roads; the type, number, and efficiency of loading machines; the parameters of ship-lifting devices, and equipment of shipyards. The architectural design type determines: the procedure of loading operations; the capacity of berths and warehouses. The type of power units determines special equipment of refueling bases and means of refueling. Changes in the parameters and indexes of the utilization of the individual elements of the parts depending on the variants of the transportation fleet (vessel) are accompanied by changes in the proportionate expenses on the reloading of cargoes.

At the present time, methods of estimating accompanying expenses on ports have been sufficiently developed [1, 8, 12, 18], but they have to be verified and developed in more detail in application to the optimal problem of the substantiation of the plan for the development of the Soviet maritime transportation fleet.

The current and one-time expenses on the technical fleet are connected with the characteristics of the largest new vessels and with the overall structure of the transportation fleet with respect to its carrying capacity.

The methods of computing expenses on dredging and their quantitative dependence on the size of the vessel can be considered as solved, but their dependence on the overall structure of the fleet has not yet been sufficiently studied.

The current and one-time expenses on the auxiliary service fleet also depend on the dimensions of individual vessels and on the overall structure of the transportation fleet; the quantitative relationships and methods of calculating the influence of the sizes of vessels and the structure of the fleet on the level of expenses on the auxiliary service fleet have not yet been studied sufficiently for solving general and special optimization problems of the development of the fleet.

The current and one-time expenses on ship repair enterprises are determined by the specialization of the vessel, its dimensions and speed, and the age structure of the fleet. As a rule, current expenses of ship repair enterprises are computed in application to vessels; methods for computing expenses on ship repairs have been worked out, but they need further refinement. Works [1, 12] contain recommendations on the determination of the capital outlay for ship repair enterprises; after some refining, these recommendations can be used for solving optimization problems of the transportation fleet.

In addition to the changes in the accompanying expenses on individual elements of the material and technical resources of the maritime transportation system, the expenses on other associated branches of the national economy (shipbuilding and fuel) will also change depending on the variant of the plan for the development of the transportation fleet.

In some works, it was proposed to compute the connected capital investments into the fuel industry [1, 12, 14]. In our opinion, this recommendation is not sufficiently grounded because it is proposed to use proportionate capital investments and the production cost of individual types of fuel rather than their prices. The attempts to use this method have shown that the existing difficulties in the determination of the average level of proportionate expenses in the fuel industry make the optimalness of the results doubtful. Therefore, the solution of the general problem should not be encumbered with insufficiently substantiated data on the fuel industry. The approved price catalog prices can be used instead. Let us note that the influence of the type of the power unit on the solution of the general problem and such intermediate problems as the substantiation of the fleet replenishment program and the effectiveness of the operating fleet is exaggerated by the authors of the above-mentioned works, because the results of preliminary studies on establishing the limits of effective use of various types of power units will always be used in computing the varients of vessels.

The problem of computing associated expenses in the shipbuilding industry is more complicated. The effect of series construction on the building costs of vessels has now been studied sufficiently. However, there still are no prices for vessels with the exception of some individual types. Considering the determining role of the cost of construction in the effectiveness indexes, it is necessary to continue studies on establishing quantitative interrelations of series construction, production capacity of shipbuilding enterprises, parameters of vessels, and individual elements of shipyards in order to refine the methods for determining the construction costs of vessels, particularly of those types which are new to domestic shipbuilding industry. Let us add that, for some variants of the shipbuilding program which differ with respect to the presence and percentage of large-capacity vessels, the volume of associated expenses in the shipbuilding industry may vary greatly. In spite of the complexity of this problem, methods for computing associated expenses in the shipbuilding industry must be developed in the near future in order to establish quantitative interdependence of the construction costs of ships and capital investments into the shipbuilding industry on the number of vessels in the series, the capacity of shipbuilding enterprises, their location, parameters of the main elements (sizes of the building berths, characteristics of the building equipment, etc). These data will provide a basis for the optimization of the shipbuilding programs of the organizations of the Ministry of the Shipbuilding Industry and the Ministry of the Maritime Fleet, USSR.

Different Times of Capital Investments. In determining associated capital investments in the shipbuilding industry, there arises the problem of allowing for the fact that these expenses do not occur at the same time. The

necessary total capacity of the shipyards of the shipbuilding industry may change with respect to the variants of the fleet replenishment program. An increase in the total capacity of shipbuilding during a planned period will always have stepped characteristics, but the effectiveness of investments into the shipbuilding industry will depend on the correspondence of the overall capacity of the shipyards to the needs in new construction. Consequently, the time-difference factor of capital investments must be necessarily taken into consideration in developing methods for substantiating the shipbuilding program.

Methods for Solving Indiviaual Problems

The Composition of the Initial Data on Shipping and the Form of Their Presentation. Their composition and form must be taken into account so they would correspond to the requirements of the problem of the optimization of the plan for the development of the fleet. It is necessary to preserve the existing division of the total volume of the Soviet fleet shipping by the types of voyages, basins, directions, and types of cargoes. At the same time, it is necessary to have more detailed data on the types of transported cargoes, seasonal characteristics, and the sizes of shipments. This will make it possible to have a more effective determination of the effectiveness of the specialized fleet.

In the total volume of general freight, it is necessary to show separately shipments of cargoes in packages, in containers (long, large, or heavy), and on wheels. Dimensions and weights of packages and containers must be indicated; long and heavy cargoes must be grouped and graded. Perishable goods must be subdivided into those requiring special refrigeration and those requiring special conditions of shipping (temperature, moisture) in ordinary vessels.

Lumber cargoes are subdivided into sawn lumber, etc; in the total volume of each type, packaged freight is shown separately, and the weight and size of packages, as well as their percentage in the total volume are indicated.

Seasonal freight must be shown separately and the period of its shipping must be indicated.

Such differentiation of cargoes will make it possible to substantiate the level of specialization and universalization of vessels.

One of the complicated problems is the establishing of the sizes of shipments for a planned period. Sizes of shipments must be indicated whenever limitations with respect to the dimensions (carrying capacity) of vessels or shipment conditions can be expected. Methods for predicting sizes of shipments must be developed and refined further.

When giving the data on shipping, it is necessary to estimate the stability of future freight traffic separately by the types of navigation and types

of cargoes in each stage of substantiation. In addition to predicting future freight traffic, it is necessary to predict the development of regular routes where the Soviet fleet will participate.

The development of methods for grouping freight traffic is a very important problem in processing the initial data for later utilization. According to the authors of work [14], "The criteria for the enlargement of routes are approximately the same distance of shipping and conditions of processing vessels in ports". In works [13, 16], the criterion is more concrete --"it is the transportation capacity of the route" equal to the product of the shipping distance multiplied by the mean gross norm of freight handling in ports. Neither of these criteria for grouping cargo traffic and substantiating mean estimated routes is exhaustive; when the second one is used, one group may include shipping with different navigation conditions determining different requirements for the nautical characteristics of the vessels.

Methods for grouping cargo traffic should be developed further. Evidently, they can be based on the criterion of the "transportation capacity of the route" with definite limitations for various types of navigation and basins. This must be developed by providing methods for calculating future routes.

Evaluation of the Composition of the Fleet for the Beginning of the Planned Period. The composition of the fleet for the beginning of a planned period is established on the basis of refined plans for the write-off and delivery of vessels during the period preceding the planned period. Analysis is made of the structure of the fleet with respect to its purpose, tonnage groups, age, etc. Vessels whose service time expires during the planned period and outdated vessels are classed separately.

The authors of works [11, 12] proposed to group vessels of the old fleet by the criteria of their purpose and carrying capacity. Works [13, 16] also recommend to consider the speed in addition to the purpose and the carrying capacity of the vessels. The latter is more correct because it reflects the potential carrying capacity of vessels and, to a considerable degree, the proportionate cost of the tonnage content. Let us add that large series vessels in the composition of the operating fleet can be separated into independent groups.

Analysis of the Results of Utilization of the Operating Fleet

Methods for analyzing the operation of the dry-cargo, tanker, and passenger fleets have been sufficiently developed and tested. However, due to the fact that such analysis is very labor-consuming, it is possible to do it only for a limited number of routes, directions, and types of vessels, and only for a limited period. Therefore, until the analysis can be done with the use of electronic computers, generalizations of the experience in the operation of the Soviet fleet must be done for the main determining (specifying) directions of shipping and types of vessels, as well as for individual directions with sharply different operating conditions.

Evaluation of Tendencies in the Development of the World Fleet. At the present time, the evaluation of tendencies in the development of the world fleet having a definite effect on planning the development of the Soviet fleet is done on the basis of statistical and published data without any well-grounded methods of scientific prognostication. Methods for scientific prognostication and evaluation of the development of the world fleet must be developed in the next few years.

Conditions of the Utilization of the Old and New Fleets. In order to reduce the number of variants in solving optimization problems, limiting conditions are taken into consideration, including those of the utilization of vessels of the old fleet with respect to the types of navigation, directions, etc. If vessels of the new fleet have no limitations with respect to their technical conditions and economic characteristics, then the problem of the utilization of the vessels of the operating fleet at the beginning of the planned period is examined in a different way. It is pointed out in work [13] that the composition of the old fleet for the end of the planned period must be established in advance (before solving the general problem of the substantiation of the fleet development plan) and distributed by the spheres of utilization in accordance with the characteristics and technical conditions of the vessels. It was recommended to give special attention to old vessels with repect to their suitability for CFC shipping. However, these recommendations were very general and not concrete.

The spheres of the utilization of old vessels were outlined more concretely in work [14]. It is said in that work that "... vessels built according to designs developed prior to the period of future planning can participate only in coastwise and export-import shipping. For MIP [between-foreign-ports] routes, it is possible to use only the vessels of forward planning and construction." This recommendation, unlike the first one, is very categorical, but is not sufficiently substantiated. According to it, all vessels of the operating fleet (including those of the shipbuilding program of the period preceding the planned period) will be removed from participation in CFC shipping, although as a result of the experience in the utilization of the operating fleet and analysis of future conditions of CFC shipping, some types of vessels can be as effective as newly built ships. Moreover, a new replenishment program based on series construction may not have vessels of certain types which will be most effective on concrete routes of CFC. Consequently, the methods for establishing limitations in the use of vessels of the old fleet must be developed further. It is necessary to consider the technical condition of the vessels, their suitability for operation on concrete routes, and the experience in their use during the past period. These methods must cover not only the conditions of the distribution of the spheres of utilization (CFC, export-import, and coastwise shipping), but also the natural and geographic conditions, such as navigation along the Northern Sea Route and within freezing basins during the winter period. It is also necessary to consider the limitations on navigation regions imposed by the USSR Register.

In evaluating the expediency of the utilization of the old fleet during a planned period, there arises the problem of a criterion of the optimalness

48

of its utilization in evaluating the overall need in the fleet and the re-
plenishment volume. During the first stage of the substantiation of the
fleet development plan. When expanded dependences of technical and economic
characteristics are used and only direct expenditures on the fleet are con-
sidered, the established service life of the vessel can be taken as a cri-
terion of the possibility of the participation of the vessel in the overall
distribution. Vessels whose age will exceed the established normal service
term during the planned period are excluded from the carry-over volume of
the operating fleet. During the second stage, it is necessary to consider
not only the physical wear and tear of the vessels of the old fleet, but
also their obsolescence. During the third stage, the carry-over volume of
the operating fleet may be taken as constant on the basis of the results of
the substantiations of the second stage, if it is established in developing
the model that this assumption will not have a substantial effects on the
results.

Fleet Reserve. The methods used at the present time for predicting sea ship-
ping (particularly foreign trade) are not sufficiently accurate for solving
optimization problems for substantiating the plan for the development of the
transportation fleet [2]. Due to the peculiarities of long-range prediction
of foreign-trade shipping, there is almost in all instances, the possibility
of increasing the total volume of shipping through covering the export costs
of improved goods and finished articles by labor-intensive industrial raw
materials and fuels. This makes it necessary to develop methods for evaluat-
ing economically justifiable production capacity reserves of the individual
elements of the material and technical resources of the maritime transporta-
tion system, including the transportation fleet reserve. The necessity of
the transportation fleet reserve is also dictated by the general economic
conditions of the world shipping and the economic and political requirements
for marine transportation. Until recently, the size of the fleet reserve
was determined by the experience of past years. Since there are no substan-
tial methods for selecting the reserve, studies on this problem have not been
given sufficient attention. In developing such methods, it is possible either
to introduce expected freight traffic indicating the sign and value of pos-
sible deviations, or to correct the overall need in the transportation fleet
obtained as a result of solving the optimization problem on the basis of
strictly fixed freight traffic expected in the future. The first method
complicates the solution of the general problem, and the second method re-
quires thorough investigation and development of correction methods on the
basis of probable estimation of possible deviations in the characteristics
of freight traffic. It is also necessary to consider the utilization of the
reserve fleet for expanding CFC shipping.

Characteristics of New Types of Vessels. During various stages of the sub-
stantiation of the plan for the development of the transportation fleet, dif-
ferent requirements are imposed on the list of the variations in the charac-
teristics of new vessels. The main characteristics determining the type and
operational qualities of a maritime cargo vessel which must be substantiated
from the economic and operational viewpoints are: its purpose, carrying ca-
pacity (in some instances volume capacity), speed, type of architectural de-
sign, type of power unit, and automation level.

49

During the first stage of substantiating the fleet development plan, it is sufficient to vary three characteristics: purpose, carrying capacity, and speed, which determine the operational possibilities and the productive capacity of the vessel. Quantitative dependence of the technical and economic parameters of the vessel on its purpose, carrying capacity and speed is established according to enlarged norms which must reflect the most advanced level of the domestic and world shipbuilding industry with consideration for the technical progress. It is understood that vessels of new types will be equipped with the most advanced types of power units and automation devices, and will be adapted to intensive mechanized processing of cargoes. During the second stage of substantiation, all of the main characteristics of new types of vessels must be defined. The question arises whether it is necessary to vary the type of the power unit, automation level, and the type of architectural design, the process of solving the general problem, or they can be solved in advance as special problems and the results introduced into the general problem. The answer to this question depends on whether or not these data will affect the comparitive effeciency of the new types of vessels under various conditions of the operation, such as different distances of navigation, different norms of cargo handling, prices of fuel, port fees, etc.

It is evident that the efficiency of a new vessel will change for different variants of the power unit and the type of architectural design depending on the above-mentioned conditions. Therefore, variants of vessels of different designs and different types of power units must be included in the solution of the general problem. These variants must have fundamental differences: optimal variants which differ only in quantitative values of individual parts (for example, the hatch coefficient), are substantiated in advance.

The automation level will depend in a considerably lesser degree on the conditions of operation. Moreover, when substantiating it, it is necessary to consider much initial data whose quantitative interrelation cannot be substantiated in the near future because of the absence of experience. In view of the above, the automation level of vessels of new types must be substantiated in advance as a special problem and should not be modified in solving the general problem either during the second or third stage.

During the third stage of the substantiation of the fleet development plan, it is important to determine the shipbuilding program. Consequently, special attention must be given to such characteristics such as their purpose, carrying capacity, type of the power unit, and speed.

Variants in the carrying capacity during this stage can be taken in a narrow range limited by adjacent values; variants of power units are taken with consideration for the actual possibility of their delivery by specialized enterprises of the machine-building industry.

Variants of Main Characteristics. Variants of the vessel's purpose are established on the basis of studies on the structure of expected freight traffic and the composition of the operating fleet, analysis of the tendencies of

the world shipping and shipbuilding industry, and the progress in the development of the technology of cargo shipping. Vessels of narrow specialization are isolated, and their technical variants are substantiated in advance as special solutions.

In order to establish the variants of rated carrying capacities of new types of vessels of various purposes, it is recommended to take the parametric series of cargo vessels as a basis [7]. Later on, the parametric series of maritime cargo vessels must be refined with consideration for the progress in the world shipbuilding industry and the characteristics of the freight traffic.

Variants of the types of power units and automation level are determined on the basis of predictions for the development of ship machinery and instrument industry, electronics, and radio engineering with consideration for the experience in their use abroad and aboard domestic vessels.

Construction Costs, Operating Costs, and Income. The initial basis which includes norms for the economic and operational substantiation of new types of vessels and other elements of the maritime transportation system, has been developed sufficiently well and is being refined constantly.

Conditions ensuring the comparability of the computation variants are clearly stated in the methods for the effectiveness of capital investments [1, 17]. It is particularly important to ensure the comparability of the indexes of the old and new elements of the material and technical resources of the maritime transportation system. On the basis of the general thesis of work [1]: "... the production cost in the variant which is being replaced (initial variant) must not be determined by report data, but by calculations with a standard basis equal to the planned variant ...", it is possible to give the following recommendations:

construction costs of vessels of the old and new fleets, port installations, mechanization, etc, must be determined by computations based on the same methods and standards;

costs standards (cost of fuel, electric energy, suppliers, wages, etc) should be considered the same for the old equipment and for the new variants;

norms for the consuption of fuel, lubricants, electric power, size of the crew (service personnel), norms for cargo handling jobs, productivity, etc, must depend on the degree of the technical and operational level of the variants of the old and new equipment with consideration for possible improvement (deterioration) of the old variants by the time of the calculated period;

relative standards must be, as a rule, considered as constant for the old and new equipment (depreciation norms, norms of deductions for repairs, overhead expenses, etc) with the exception of those cases when they are established

depending on the parameters (characteristics) which change sharply for different variants, for example, overhead expenses depending on the wages in evaluating the effectiveness of automation.

Quite often, there arises the question for the conditions for what year it is necessary to determine the construction costs of technical equipment and current expenses on their operation in solving optimization problems taking into consideration that its service life differs and in some instances is 25, 50, and more years. There are various recommendations for calculating current expenses: a) to consider expenses for the conditions of a year corresponding to one half of the service life (for vessels, 10-12 years); b) to consider expenses for the conditions of the 10th year after the beginning of the planned period: c) consider expenses for the conditions of the 5th year. In our opinion, it is more expedient to determine expenses for the conditions of the rated year of the first planned period; in this case, computations can be based on the current prices, wages, and tariffs with consideration for their possible changes during the planned period.

There are no established prices on many kinds of technical equipment of the maritime transportation system, including vessels. In this connection, methods for determining their construction costs are very important for solving the optimization problems. Research and planning organizations are constantly developing the necessary standards, however, some of their solutions in application to the requirements of the optimization problem still remain debatable.

As has been mentioned before, the rated year must be the year for whose condition the optimization problem is being solved; most frequently, it will be the final year of the planned period. The costs of vessels, machines and devices built abroad are taken for the manufacturing (construction) conditions in the USSR. During the first stage, average sectorial norms may be taken; during the second stage -- average sectorial norms for vessels, and norms differentiated by basins for ports and plants; during the third stage -- the norms must be concretized as much as possible by economic regions of the country.

The general theses should be studied thoroughly to determine the influence of differentiation on the optimalness of the answer and the possibility of their realization. Special attention must be given to the substantiation of methods for reducing currency expenses and revenues to a comparable form by means of common or differentiated equivalents.

In solving the optimization problem of substantiating the fleet development plan, there also occur other, less important, problems with respect to the determination of construction costs and current operating expenses of vessels and shore installations, however, it is not necessary to dwell on them in detail in this work.

It follows from the above that: the norms and methods of computing current and one-time expenses of the fleet, ports, and plants must be improved

further; it is necessary to develop norms of various degrees of detailedness for solving problems at different stages; in developing the norms, it is necessary to use widely modern methods of mathematical statistics and prognostication; methods for computing current and one-time expenses must allow for the possibility of using electronic computers.

<center>
*

*   *
</center>

Scientific and planning organizations of the maritime transportation system are conducting extensive work on the improvement of the methodology and norms for substantiating the plans for the development of the material and technical resources of the maritime transportation system, particularly its fleet. However, the adopted methodological approach to the solution of such a large problem contained insufficiently grounded prerequisites: division of the problems of substantiating the types of new vessels, the replenishment program and overall need in the fleet, as well as a limited use of mathematical methods and electronic computers (most problems of technical and economic substantiation of the fleet development plan were solved by the methods of elementary mathematics and manual computations).

The problem of substantiating new types of vessels for replenishing the fleet in the next planned period is a special problem in relation to the general problem of substantiating the fleet development plan. Its isolation from the general problem and the utilization of the method of selecting the optimal type of a vessel from several competing variants by evaluating their comparative effectiveness along one of several "typical" rated routes cannot correspond to the conditions of solving optimalization problems of such complexity for the following reasons:

-- the problem of determining the optimal type characteristics of vessels for future replenishment is a typical planning problem; therefore, the selection of the optimal variant must be solved on the basis of the evaluation of the economic effectiveness of all its components;

--- in selecting the optimal variant of the replenishment plan, it is necessary to consider not only the conditions connected with individual objects, but also the overall (national economic) conditions (potentialities of the shipbuilding industry, the volume of allotted capital investments, etc).

-- the program of fleet replenishment with promising types of vessels depends substantially on the existing tonnage; the number and the main characteristics of vessels of the operating fleet determine, to a considerable degree, the selection of the optimal type characteristics of new vessels;

-- new types of vessels are intended for satisfying the needs in marine shipping with a complex structure of freight traffic with changing and sometimes indefinite freight volumes along concrete routes; therefore, optimal type characteristics cannot be selected just on the basis of the maximum efficiency of individual types of vessels along individual "typical" routes.

<center>53</center>

Consequently, in order to improve the methods of substantiating new types of vessels for solving the optimization problem, it is necessary to evaluate the economic effectiveness of all transportation vessels, i.e., the general optimal need in the fleet.

The complexity and insufficient definiteness of mathematical interrelations between independent variables (the problem of selecting optimal types of vessels -- their main characteristics) and dependent variables (economic indexes for variants of vessels, technical and economic characteristics of other elements of the maritime transportation system) determine practical unacceptability of solving the problem of substantiating the optimal types of new vessels within the general problem of substantiating the fleet development plan by analytic methods and make it necessary to use the variant methods of studies.

The consideration of a large number of interrelated factors and the establishment of their quantitative evaluation and nature of their influence on final result of the solution predetermined the use of mathematical methods of economic studies and the use of electronic computers. This will ensure analysis of a larger number of variants of the optimization of the overall need in the fleet, inclusion of the vast amount of ecomony information, and exclusion of the optimization of individual vessels for individual "typical' routes. The use of mathematical methods and electronic computers will also make it possible to evaluate the stability of the obtained results correctly.

Solving the problem by mathematical methods requires complete and strict economic and mathematical formalization. Correct formalization of economic and mathematical model is the most important stage in solving optimization problems. The use of mathematical methods in solving a number of problems which are modifications of the problem of optimal utilization of available resources has been developed also in application to the substantiation of the development of the technical resources of the marine and river transportation. However, in formulating these problems, a number of assumptions were made and some insufficiently studied conditions (dynamism of the initial basis -- freight traffic, influence of series construction, production capacity and level of expenses in the enterprises of the shipbuilding industry, etc) were omitted. Thus, economic and mathematical formulation of the problem of substantiating new types of vessels by mathematical methods requires further development and refinement.

Apart from the economic-mathematical model, the results of the solution of any optimization problem are determined to a considerable degree by how well developed and substantiated the initial normative basis is. Analysis of the fundamental principles determining the mathodological approach to the substantiation of individual important norms, methods of reducing technical and economic norms to a comparable form, the level of detailedness of the norms, etc, has shown that additional studies are needed in order to develop a methodology for substantiating the normative basis and quantitative relationship of the norms.

BIBLIOGRAPHY

1. "Vremennaya metodika opredeleniya ekonomicheskoy effektivnosti kapital'-
   nykh vlogheniy na morskom transporte" [Provisional Methods for Determin-
   ing the Economic Effectiveness of Capital Investments into the Maritime
   Transportation System], Moscow, Reklambyuro MMF, 1069.

2. Rodin, Ye. D. "Fundamental Problems in Scientific Development of Long-
   Range Plans for the Development of Marine Transportation," TRUDY SOYUZ-
   MORNIIPROYEKTA [Transactions of the State Planning, Design and Scienti-
   fic Research Institute of Marine Transportation of the Ministry of the
   Maritime Fleet, USSR], No 25 (31), Moscow, Transport, 1969.

3. Arsen'yev, S. P. "Selection of Vessel Types for the Transportation
   Fleet," TRUDY TsNIIEEVTa [Transactions of the Central Scientific Research
   Institute of Economics and Operation of Water Transportation], No 50,
   Moscow, Transport, 1968.

4. Bakayev, V. G. "Ekspluatatsiya morskogo flota" [Operation of the Mari-
   time Fleet], Moscow, Transport, 1965.

5. Guerevich, G. Ye. "Organizatsiya raboty morskogo flota" [Organization
   of the Maritime Fleet Operations], Moscow, Transport, 1961.

6. Krayev, V. I. "Methods for Economic and Operational Substantiation of
   the Main Technical Characteristics of Maritime Cargo Vessels," TRUDY
   TsNIIMFa [Transactions of the Central Scientific Research Institute of
   the Maritime Fleet], No 65, Leningrad, Transport, 1965.

7. Krayev, V. I.; Limonov, E. L.; and Stupin, O. K. "Problems of Substan-
   tiating Cargo-Carrying Capacity and Speed of Vessels Planned for Construc-
   tion," TRUDY TsNIIMFa, No 94, Leningrad, Transport, 1968.

8. "Methods of Economic and Operational Substantiation of the Most Important
   Technical Characteristics of Maritime Cargo Vessels," TEKHNICHESKIY
   OTCHET [Technical Report] TsNIIMFa, 1965.

9. Dmitriyeva, N. Ye. "Application of Mathematical Methods in Planning
   Operations of the Maritime Fleet," TRUDY TsNIIMFa, No 37, Leningrad,
   Morskoy Transport, 1961.

10. Dmitriyeva, N. Ye.; Khalif, A. I.; and Chalov, V. V. "Applica-
    tion of Mathematical Methods and Electronic Computers in Determining
    the Effectiveness of Capital Investments into the Replenishment of the
    Maritime Transportation Fleet," TRUDY TsNIIMFa, No 70, Leningrad, Trans-
    port, 1966.

11. Novikov, O. A., and Pantin, A. A. "Fundamental Principles of the Method
    for Determining the Economic Effectiveness of Capital Investments into

Planned Replenishment of the Maritime Transportation Fleet," TRUDY TsNIIMFa, No 70, Leningrad, Transport, 1966.

12. Pantin, A. A. "Methodological Principles for Developing a Program for Replenishing the Transportation Fleet and Evaluation of Its Economic Effectiveness," TRUDY TsNIIMFa, No 101, Leningrad, Transport, 1969.

13. Slavin-Borovskiy, B. B. "Some Problems of General Methodology for Substantiating the Shipbuilding Program of Marine Transportation; TRUDY SOYUZMORNIIPROYEKTA, No 21(27), Moscow, Transport, 1968.

14. Pashin, V. M.; Dorin, V. S.; and Soldatov, V. Ye. Application of Economic Mathematical Methods and Electronic Computers in Designing Vessels," SUDOSTROYENIYE [Shipbuilding], No 11, 1967.

15. Novikov, O. A., and Pantin, A. A. "Methodological Principles of Developing Scientifically Substantiated Plans for the Development of the Material and Technical Resources of the Maritime Transportation System," TRUDY TsNIIMFa, No 65, Leningrad, Transport, 1965.

16. Slavin-Borovskiy, B. B. "A Method of Consolidated Computations for Determining the Need in the Replenishment of the Fleet in the Future by Types of Vessels," TRUDY SOYUZMORNIIPROYEKTA, No 7 (13), Moscow, Transport, 1965.

17. "Tipovaya metodika opredeleniya ekonomicheskoy effectivnosti kapital'-nykh vlozheniy" [Standard Methods for Determining the Economic Effectiveness of Capital Investments], AN SSSR, Gosplan SSSR, Gosstroy SSSR, Moscow, Izd AN SSSR, 1969.

18. Pantin, A. A. "Substantiation and Selection of Optimal Dimensions of Vessels with Consideration for Port Expenses," TRUDY TsNIIMFa, No 52, Leningrad, Morskoy transport, 1963.

DETERMINATION OF THE COEFFICIENT OF THE VESSEL'S ADAPTEDNESS FOR RAPID CARGO HANDLING FOR THE OVERALL EVALUATION OF THE LEVEL OF ITS OPERATION AND TECHNICAL EFFICIENCY   pp 59-70

[Article by S. V. Layner, Candidate of Engineering Sciences]

The degree of the adaptedness for rapid cargo handling is one of the most important characteristics of a dry-cargo vessels which determines, to a considerable degree, the level of its operational and technical efficiency. The coefficient of adaptedness must be understood to be the ratio of the potential intensiveness of cargo handling to the cargo-carrying capacity of of the vessel. This concept differs from the existing idea that the degree of the adaptedness of a vessel for cargo handling is determined by the intensiveness of cargo handling regardless of the size of the vessel. In our opinion [1], only the ratio of the intensiveness of cargo handling to the cargo-carrying capacity of a vessel characterizes its adaptedness for rapid cargo handling. Two vessels characterized by the same intensitiveness of cargo handling (for example, 1,000 tons in 24 hours) are not identically adapted for cargo handling if these vessels are of different cargo-carrying capacities, for example, 9,000 and 6,000 tons, because, with all other conditions being equal, the in-port-time coefficient for the first vessel will be 1.5 times greater than for the second vessel.

The intensiveness of processing ships in ports is affected by many factors. The following are the factors depending on the ship's design:

number of holds, hatches, and the displacement of the hatch in relation to the center of the hold;

the degree of opening of the cargo compartments of the vessel, which is determined by the ratio of the cubic volume of the hatch aperture to the capacity of the cargo compartment;

the degree of unevenness in the distribution of cargo-carrying capacity among individual cargo compartments, equal to the ratio of the vessel's cargo-carrying capacity to the product of the capacity of the largest hold multiplied by the total number of holds;

the degree of conveniences of cargo stowage in the hold, or the coefficient of the hold shape [2], which is equal to the ratio of the hold capacity to the product of its length, width, and height;

architectural design of cargo compartments, number of decks, the presence of stanchions, protruding parts of the framing, arrangement of the engine and boiler room, deck superstructures, etc;

the type, number, lifting capacity and efficiency of the cargo handling equipment (when the vessel uses, chiefly, its own equipment for cargo handling).

It should be kept in mind that a vessel adapted for rapid handling of some types of cargoes may be less adapted for handling some other types. According to the Norms for Cargo Handling [3], each dry-cargo vessel belongs simultaneously to two groups: with respect to packaged and bulk cargoes.

In order to develop numerical methods for comparing the adaptedness of individual types of vessels for cargo-handling, it is necessary to have much technical data which sometimes are difficult to obtain, particularly when domestic vessels are compared with foreign vessels. Therefore, hereafter, we shall base our approximate evaluation of the adaptedness of individual types of vessels for cargo handling on the data which are usually published in special Soviet and foreign periodicals.

In accordance with the Norms of Cargo Handling, the classification of individual cargo compartments for computing overall output norms is done depending on the dimensions of the cargo hatch (length, width) and the space under the deck measured from the hatch coaming to the nearest transverse bulkhead or the through longitudinal bulkhead. Auxiliary hatches with an area of less than 10 m² which do not have cargo handling equipment are not considered in the computations. Depending on the values of these parameters, all cargo compartments are subdivided into six classes.

Individual cargo compartments are placed in different classes; but the vessel group is determined on the basis of the weighted average (with respect to the cargo-carrying capacity) class of cargo compartments.

Hatches from 20 to 30 m are considered as two hatches, from 30 to 45 m -- as 3 hatches, and over 45 m -- as four hatches.

The accepted classification of individual cargo compartments is also used in computing the vessel-hour norms of cargo handling. For this, vessels are classified depending on the number of cargo hatches, the coefficient of structural nonuniformity of the holds, and the class of individual cargo compartments of the vessel.

Considering the significance of the characteristics of individual cargo compartments for computing overall output norms and vessel-hour norms, we studied the effects of the degree of exposure of the hold (hatch capacity coefficient)

58

and the location of the hatch in relation to the hold on the intensiveness
of handling packaged cargoes. The computations were done on the basis of
the data on timing loading-unloading operations conducted by Lenmorniiproyekt
[expansion unknown] on vessels of the "Poltava" and "Krasnograd" types in
the ports of Odessa, Batumi, and Leningrad. The intensiveness of cargo
handling was determined by the zones of cargo compartments: in the hatch
opening and in the zones below the deck at every meter away from the hatch
coamings.

The processing of the results of the chronometration showed that cargo hand-
ling in the hatch opening was approximately 1.5 times more intensive than
in the third zone and twice as intensive than in the sixth zone (Table 1).

<div align="center">Table 1</div>

(1) Зоны / грузовых помещений	(2) Выгрузка сахара в мешках, т/люко-ч	Погрузка генеральных (3) грузов в ящиках, т/люко-ч
Просвет люка (4)	82,5	57,6
1-я зона (5)	70,2	49,1
2-я "	61,2	42,8
3-я "	54,2	37,9
4-я "	48,6	34,0
5-я "	44,1	30,8
6-я "	40,4	28,2

Key: 1. Zones of cargo compartments
2. Unloading bags of sugar, ton/hatch-hour
3. Loading general cargoes in boxes, ton/hatch-hour
4. Hatch opening
5. First zone

In order to establish the dependence of average intensity of handling pack-
aged cargoes (for the hold as a whole) on the degree of exposure of the hold,
we studied a 20 x 20 m hold, 10 m high; the exposure coefficients varied from
0.16 (hatch opening 8 x 8 m) to 1.0 (completely exposed hold). The diagram
of hatch exposure is shown in Figure 1.
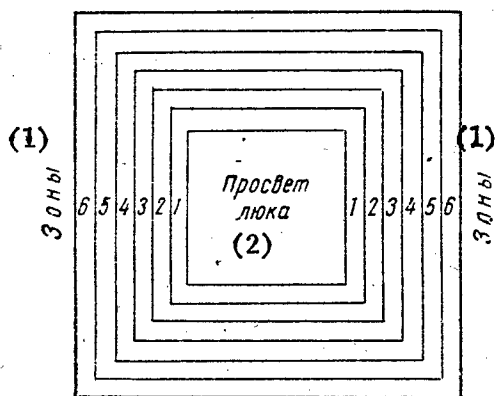
Figure 1. Central Position of the Hatch

Key: 1. Zones
2. Hatch opening

Having established the holding capacity and the amount of cargo in each zone and taking the relative loading volume of the general cargo to be 2 m³/t, we find the length of handling. Summing up the handling time of all zones, we obtain the handling time of the entire hold for each given hatch capacity coefficient. The results of the computations are shown in Table 2.

Table 2

Показатели (1)	просвет люка (3)	1-я	2-я	3-я	4-я	5-я	6-я	Всего (4)
(2) Зоны грузового пространства								
(5) Интенсивность погрузки генеральных грузов в ящиках, т/люко-ч . .	57,6	49,1	42,8	37,9	34,0	30,8	28,2	—
(6) Площадь зон, м² . . .	64	36	44	52	60	68	76	400
(7) Объемы зон, м³	640	360	440	520	600	680	760	4000
(8) Количество генеральных грузов, т	320	180	220	260	300	340	380	2000
(9) Время обработки, ч, при $K_л$:								
0,16	5,6	3,7	5,1	6,9	8,8	11,0	13,5	54,6
0,25	5,6	3,1	4,5	6,1	7,9	10,0	12,3	49,5
0,36	5,6	3,1	3,8	5,3	7,0	9,0	11,2	45,0
0,49	5,6	3,1	3,8	4,5	6,1	7,9	10,0	41,0
0,64	5,6	3,1	3,8	4,5	5,2	6,9	8,9	38,0
0,81	5,6	3,1	3,8	4,5	5,2	5,9	7,8	35,9
1,0	5,6	3,1	3,8	4,5	5,2	5,9	6,6	34,7

Key: 1. Indexes
2. Zones of cargo space
3. Hatch openings
4. Total
5. Loading intensiveness of general cargoes in boxes, tons/hatch-hour
6. Zone area, m³
7. Zone volume, m³
8. Amount of general cargo, tons
9. Handling time, hours at $K_л$ (hatch capacity coefficient)

Knowing the time needed for handling the hold at various hatch capacity coefficients $K_л$, let us determine the intensiveness of handling hold M depending on $K_л$ and establish the correlation between them. As can be seen from Table 3, when $K_л$ increases by 3 times (from 0.16 to 0.49), M increases only by one-third, when $K_л$ increases by 4 times, M increased by 45 percent, and when $K_л$ increased by 6 times, M increases by 58 percent.

Table 3

(1) Площадь люка, м²	(2) Коэффициент лючности $K_л$		(3) Время обработки, ч	(4) Интенсивность обработки M		$\sqrt[4]{K_л}$		(5) Прирост M с увеличением $K_л$ на 1%, %
	(6) абсолютные величины	%		(7) т/люко-ч	%	(6) абсолютные величины	%	
1	2	3	4	5	6	7	8	9
64	0,16	100	54,6	36,6	100	0,63	100	—
100	0,25	156	49,5	40,4	110	0,71	113	0,18
144	0,36	225	45,0	44,5	122	0,78	124	0,17
196	0,49	306	41,0	48,8	133	0,84	133	0,16
256	0,64	400	38,0	52,7	145	0,89	141	0,15
324	0,81	507	35,9	55,7	153	0,95	151	0,13
400	1,00	625	34,7	57,6	158	1,00	159	0,11

Key: 1. Hatch area, m^2
2. Hatch capacity coefficient, $K_л$
3. Handling time, hours
4. Handling intensiveness, M
5. Increase of M as $K_л$ increases by 1 percent, percents
6. Absolute values   7. Ton/hatch-hour

The interrelation between $K_л$ and M can be expressed sufficiently accurately for practical purposes by the expression

$$M = AK_л^{0,25}$$

or

$$\frac{M_1}{M_2} = \frac{\sqrt[4]{K_{л1}}}{\sqrt[4]{K_{л2}}}.$$

This relation can be traced easily by comparing the figures of the 6th and 8th columns of Table 3. The decrease in the increment of M with increasing $K_л$ can be judged by the data of the 9th column of the same table.

It should be stressed that the interrelation found between $K_л$ and M refers only to the loading and unloading of packaged cargoes in bags, boxes, and bales. When larger or heavier cargoes are handled, the interrelation between $K_л$ and M will be different because of technological peculiarities of handling heavy cargoes, complexity of moving them outside of the hatch opening horizontally and vertically, and a great difference in the intensity of their handling in the opening of the hatch and in the hold pockets.

Table 4 shows the results of the computation of the average intensiveness of heavy cargoes depending on the hold exposure coefficient which show that the average intensiveness of handling heavy cargoes is almost directly proportional to the hold exposure coefficient. The effectiveness of open-type

61

vessels shows the most in transporting heavy cargoes, equipment, cargoes in packages, containers, and trays, etc.

Table 4

(1) Показатели	(7) Тип судна		
	(8) „Полтава"	„Красноград" (9)	„Лениногорск" (10)
(2) Коэффициент лючности $K_л$	0,83	0,61	0,40
(3) То же, %	100	73	48
(4) Интенсивность грузовых работ в подпалубных карманах, $т/люко-ч$	34,5	17,6	12,0
(5) Средняя интенсивность по всему трюму:			
(6) (в просветах люка = = 86,5 $т/люко-ч$)	77,7	59,6	41,8
(3) То же, %	100	77	54

Key: 1. Indexes
2. Hatch capacity coefficient, $K_л$
3. Same, percent
4. Intensiveness of cargo handling in pockets under the deck, ton/hatch-hour
5. Average intensiveness for the entire hold:
6. (in hatch openings = 86.5 tons/hatch-hour)
7. Type of vessel
8. "Poltava"
9. "Krasnograd"
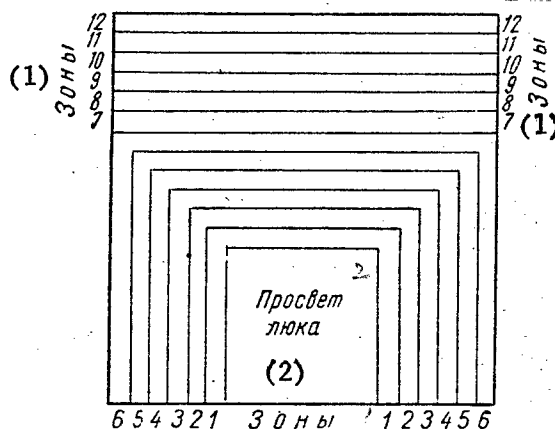10. "Leninogorsk"

Figure 2. Extreme Position of the Hatch
Key: 1. Zones
2. Hatch opening

Let us examine the effect of the displacement of the hatch in relation to the center of the hold on the average intensiveness of cargo handling on an

Table 5

Показатели (1)	Просвет люка (7)	Зоны грузового пространства (6)												Всего (8)
		1-я	2-я	3-я	4-я	5-я	6-я	7-я	8-я	9-я	10-я	11-я	12-я	
(2) Интенсивность погрузки ящиков, т/люко-ч	57,6	49,1	42,8	37,9	34,0	30,8	28,2	25,9	23,8	21,9	20,1	18,5	17,0	—
(3) Количество груза, т	320	130	150	170	190	210	230	100	100	100	100	100	100	2000
(4) Время обработки, ч, при $K_л$:														
0,16	5,6	2,6	3,5	4,5	5,6	6,8	8,2	3,9	4,2	4,6	5,0	5,4	5,9	65,8
0,225	5,6	2,3	3,1	4,0	5,0	6,2	7,5	3,6	3,9	4,2	4,6	5,0	5,4	60,4
0,30	5,6	2,3	2,6	3,5	4,4	5,5	6,8	3,3	3,6	3,9	4,2	4,6	5,0	55,3
0,385	5,6	2,3	2,6	3,0	3,9	4,9	6,1	2,9	3,3	3,6	3,9	4,2	4,6	50,9
0,48	5,6	2,3	2,6	3,0	3,3	4,3	5,4	2,6	2,9	3,3	3,6	3,9	4,2	47,0
0,585	5,6	2,3	2,6	3,0	3,3	3,6	4,7	2,3	2,6	2,9	3,3	3,6	3,9	43,7
0,70	5,6	2,3	2,6	3,0	3,3	3,6	4,0	2,0	2,3	2,6	2,9	3,3	3,6	41,1
0,75	5,6	2,3	2,6	3,0	3,3	3,6	4,0	1,7	2,0	2,3	2,6	2,9	3,3	39,2
0,80	5,6	2,3	2,6	3,0	3,3	3,6	4,0	1,7	1,7	2,0	2,3	2,6	2,9	37,6
0,85	5,6	2,3	2,6	3,0	3,3	3,6	4,0	1,7	1,7	1,7	2,0	2,3	2,6	36,4
0,90	5,6	2,3	2,6	3,0	3,3	3,6	4,0	1,7	1,7	1,7	1,7	2,0	2,3	35,5
0,95	5,6	2,3	2,6	3,0	3,3	3,6	4,0	1,7	1,7	1,7	1,7	1,7	2,0	34,9
1,0	5,6	2,3	2,6	3,0	3,3	3,6	4,0	1,7	1,7	1,7	1,7	1,7	1,7	34,6
(5) Интенсивность погрузки в отдельных зонах, %	100	85	74	66	59	54	49	45	41	38	35	32	29	—

Key: 1. Indexes
2. Loading intensiveness of boxes, ton/hatch-hour
3. Amount of cargo, tons
4. Handling time, hours, at $K_л$:
5. Loading intensiveness in individual zones, percent
6. Zones of cargo space
7. Hatch opening
8. Total

example of the same hold (20 x 20 x 10) but with a hatch located directly next to the transverse bulkhead (Figure 2). This hold was also subdivided into individual zones, but their number was increased to twelve; the areas and the cubic content of individual zones and, consequently, the hold exposure coefficients were somewhat different from those in the hold where the hatch was located centrally.

Table 5 gives the results of the computation of the length of handling general cargoes when the hold exposure coefficients were from 0.16 to 1.0, and Table 6 shows the results of the computation of the intensiveness of cargo handling. As can be seen from Table 6, the interrelation between the hold exposure coefficient K_π and the intensiveness of cargo handling M has approximately the same characteristics as when the hatch was located centrally. The increase of K_π by 3 times (0.16 and 0.48) leads to an increase of M by only 41 percent, by 5 times (0.16 and 0.80) -- by 75 percent, and by 6.25 times -- by 90 percent.

Table 6

(1) Площадь люка, $м^2$	(2) Коэффи- циент лючности, $K_л$	(3) Показатели				
		время обработки, ч (8)	интенсивность обработки M, т/люко-ч (4)	коэффи- циент люч- ности, % (5)	интенсивность обработки M, % (6)	Прирост M с увеличением $K_л$ на 1%, % (7)
64	0,16	65,8	30,4	100	100	—
90	0,225	60,4	33,1	141	110	0,24
120	0,30	55,3	36,2	187	120	0,23
154	0,385	50,9	39,3	241	129	0,21
192	0,48	47,0	42,7	300	141	0,20
234	0,585	43,7	45,8	366	151	0,19
280	0,70	41,1	48,7	437	160	0,18
300	0,75	39,2	51,0	468	168	0,18
320	0,80	37,6	53,2	500	175	0,18
340	0,85	36,4	54,8	530	180	0,18
360	0,90	35,5	56,3	562	185	0,18
380	0,95	34,9	57,3	593	188	0,18
400	1,0	34,6	57,6	625	190	0,17

Key: 1. Hatch area, m^2
2. Hatch capacity coefficient, K_π
3. Indexes
4. Handling intensiveness M, ton/hatch-hour
5. Hatch capacity coefficient, percent
6. Handling intensiveness M, percent
7. Increment of M when K_π increases by 1 percent, percent
8. Handling time, hours

Table 7

Коэффициент лючности, $K_{л}$ (1)	(2) Интенсивность грузообработки, $т/люко-ч$		Отношение интенсивностей при центральном и крайнем расположении люков (6)
	(3) расположение люка		
	(4) крайнее	(5) центральное	
0,16	30,4	36,6	1,22
0,25	34,1	40,4	1,18
0,36	38,2	44,5	1,16
0,49	43,0	48,8	1,14
0,64	47,6	52,7	1,11
0,81	53,5	55,7	1,04
1,00	57,6	57,6	1,00

Key: 1. Hatch capacity coefficient, $K_{л}$
2. Intensity of cargo handling, ton/hatch-hour
3. Position of the hatch
4. Extreme
5. Central
6. Intensiveness ratio for central and extreme position of hatches

Table 7 shows how much the handling of general cargoes is more intensive in holds with centrally located hatches than in holds with hatches near the bulkheads with the same vlues of $K_{л}$. If $K_{л}$ does not go beyond the limits of 0.5-0.6, then the intensiveness of cargo handling is higher by 12-14 percent when the hatch is located centrally. It should be noted that the variant of extreme locations of the hatch is rare, and that the displacement of the hatch in relation to the center of the hold usually does not exceed 2-3 m. Therefore, the difference in the value of M does not exceed 5 percent. In any case the displacement of centers does not have such a great significance as many believe (for example, see work [4]). In most instances, it can be disregarded in the first approximation.

In connection with the above, the classification of individual cargo compartments in vessels given in the Norms for Cargo Handling appears to be insufficiently substantiated. According to this classification, holds with hatches from 9x6 to 20x10 m and more belong to the same class. However, as has been shown above, for 9x6 m hatches $K_{л} = 0.135$, and 20x10 m hatches $K_{л} = 0.50$. In the second case, the intensiveness of cargo handling is 35 percent higher than in the first case.

The sizes of hatches shown in the Norms for Cargo Handling do not cover all possible variants because there are gaps between them (for example, how to class a hold with a 8.8 x 7.5 m hatch). Evidently, it is more expedient to replace the classification of holds depending on the sizes of hatches and distances to the sides and bulkheads by the classification according to the hatch capacity coefficient.

As for the statement in the Norms to the effect that hatches from 20 to 30 m are considered as two hatches, from 30 to 45 m -- as three hatches and over 45 m -- as four hatches, these jumps appear to be completely ungrounded. For example, is it possible to organize three mechanized lines near a hatch 31 m long, if, in addition to this hatch, the vessel has two more -- at the bow and at the stern? Evidently, the problem of making one long hatch equal to a certain number of hatches greater than one should be solved depending on the possibility of organizing two or more mechanized lines and their comparative efficiency. From this viewpoint, there should not be such sharp jumps as equating one hatch with two, three, or four hatches.

Allowing for the possibility of organizing more than one mechanized line for long hatches, the rated number of mechanized lines per each hold depending on the length of the hatch can be taken from Table 8 as suggested by us [5].

Table 8

(1) Длина люка, м	Число механизи-(2) рованных линий	(1) Длина люка, м	Число механизи-(2) рованных линий
До 15	1,0	20—21	1,6
15—16	1,1	21—22	1,7
16—17	1,2	22—23	1,8
17—18	1,3	23—24	1,9
18—19	1,4	Свыше 24	2,0
19—20	1,5		

Key: 1. Length of hatch, m
2. Number of mechanized lines
3. Up to 15
4. Over 24

As was mentioned before, according to the current Norms for Cargo Handling, the classification of vessels for computing vessel-hour norms is done, in part, depending on the coefficient of structural nonuniformity of hatches. In order to complete cargo handling in holds at the same time and shorten the time of cargo handling operations, it is desirable that cargo holds should have the same capacity as much as possible. However, there are very few vessels with holds of equal capacities, because usually, due to the buoyancy requirements, the capacities of the extreme holds are smaller than those of the middle holds. When the engine and boiler room is at the stern, the hold at the bow is the smallest. However, experience shows that structural nonuniformity does not fully reflect the nonsimultaneity of handling all hatches of the vessel.

In order to complete cargo handling operations in all hatches at the same time, it is not necessary for them to have the same capacity, because in the end hatches, which usually have irregular shapes, the intensiveness of

66

cargo handling is lower than in the middle holds. As for the vessels having one or two large holds with long hatches, the computation of the intensiveness of cargo handling for them must be done with consideration for the probable number of mechanized lines according to Table 8. Then, the coefficient of nonsimultaneity of handling is usually greater (closer to 1) than the coefficient of structural nonuniformity.

Computation of the coefficient of nonuniformity of the distribution of the cubic capacities of holds for five types of vessels with consideration for the number of mechanized lines for individual holds is shown in Table 9.

Table 9

Показатели (1)	Тип судна (2)				
	"Полтава" (3)	"Муром" (4)	"Красно-град" (5)	"Выборг" (6)	"Ленино-горск" (7)
Вместимость трюмов (8)					
№ 1	1 375	1 617	2 100	1 708	1 629
№ 2	2 965	3 581	2 709	3 067	3 667
№ 3	3 360	5 808	5 584	5 176	4 141
№ 4	5 450	3 471	3 186	3 023	4 618
№ 5	3 245	2 327	2 411	1 626	1 768
(9) Всего	16 395	16 804	15 990	14 600	15 823
(10) Коэффициент конструктивной неравномерности . .	0,61	0,58	0,58	0,57	0,69
(11) Количество линий у наибольшего трюма	№ 4—2	№ 3—1,6	№ 3—1,8	№ 3—1,5	1
(12) Вместимость наибольшего трюма с учетом количества линий	3 360	3 600	3 186	3 460	4 618
(13) Скорректированный коэффициент неравномерности	0,80	0,80	0,87	0,77	0,69
(14) То же, %	100	100	109	96,3	86,0

Key: 1. Indexes
2. Type of vessel
3. "Poltava"
4. "Murom"
5. "Krasnograd"
6. "Vyborg"
7. "Leninogorsk"
8. Hold capacity
9. Total
10. Coefficient of structural nonuniformity
11. Number of lines at the largest hold
12. Capacity of the largest hold with consideration for the number of lines
13. Corrected coefficient of nonuniformity
14. Same, percent

67

Table 10

Показатели (1)	(2) Тип судна				
	„Полтава" (3)	„Муром" (4)	„Красно-град" (5)	„Выборг" (6)	„Ленино-горск" (7)
(8) Генеральный груз, тыс. т .	8,63	8,65	8,0	8,05	8;2
(9) Количество трюмов/люков	5/5	5/5	5/5	5/5	5/5
(10) Коэффициент раскрытия трюмов с учетом пространства в пределах 1 м по периметру . . .	0,83	0,55	0,61	0,57	0,40
(11) Коэффициент неравномерности кубатуры трюмов с учетом количества механизированных линий .	0,80	0,80	0,87	0,77	0,69
(12) Коэффициент интенсивности грузовых работ . . .	3,3	2,2	2,6	2,2	1,3
(13) То же, %	100	67	79	67	39
(14) Коэффициент приспособленности к грузообработке	0,38	0,25	0,32	0,27	0,16
(12) То же, %	100	66 .	84	71	42

Key: 1. Indexes
2. Type of vessel
3. "Poltava"
5. "Krasnograd"
6. "Vyborg"
7. "Leninogorsk"
8. General cargo, thousand tons
9. Number of holds/hatches
10. Coefficient of hold exposure with consideration for space within the limits of 1 m along the perimeter
11. Coefficient of nonuniformity of the cubic capacity of the holds with consideration for the number of mechanized lines
12. Coefficient of cargo handling intensiveness
13. Same, percent
14. Coefficient of adaptedness for cargo handling

It should be mentioned that, when this factor is taken into consideration, the relative effectiveness of various types of vessels with respect to the index of nonuniformity also changes; before the correction, the highest coefficient was for vessels of the "Leninogorsk" type, and after the correction, this type of vessels moved to the last place.

Thus, on the basis of the definition of the coefficient of adaptedness for cargo handling, we come to the conclusion that, as a first approximation, it

68

can be expressed numerically as a product of the number of hatches n, the hatch capacity coefficient $K_\text{л}$, and the corrected coefficient of hold non-uniformity $K_\text{H.T}$ divided by the amount of cargo which the vessel can take on the basis of its tonnage and cargo-carrying capacity Q:

$$\eta = \frac{nK_\text{л}K_\text{и.т}}{Q},$$

where $nK_\text{л} K_\text{H.T}$ is the coefficient of cargo handling intensiveness.

It should be kept in mind that the exponent of the hatch capacity coefficient must allow for the type of cargo. For example, for shipping packaged cargoes (see Table 3), the exponent must be equal to 0.25; for transporting heavy cargoes, it should be equal to 1.

Considering the tendency of shipping general cargoes in large lots (in containers, packages, on trays) and the growth of the shipping volume of equipment, steel structures, and, in general, large heavy cargoes, it is possible to take that the coefficient of the adaptedness for cargo handling for general-purpose vessels is proportional to the hatch capacity coefficient. Table 10 shows computations of the values of this coefficient for the above-mentioned group of vessels for shipping cargoes in large containers with relative loading volume of 2 m^3/ton.

The values of the index of the adaptedness for cargo handling shown in Table 10 can be used for overall evaluation of the operational and technical efficiency of the above-mentioned types of vessels. This method can also be used to compute the values of the index of the adaptedness of other types of vessels for cargo handling.

<div align="center">BIBLIOGRAPHY</div>

1. Layner, S. V. "Methods for Comparative Evaluation of Operational and Technical Efficiency of Cargo Vessels," MORSKOY FLOT [Maritime Fleet], No 8, 1962.

2. Chapman, K. R. "The Optimum Machinery Position in Dry Cargo Vessels," TRANS N E COAST INST ENG AND SHIPBUILDERS, Vol 81, No 8, pp 371-400, 1965.

3. "O normakh obrabotki sudov v morskikh portakh i portovykh punktakh" [On the Norms of Cargo Handling on Vessels in Seaports and Port Points], Moscow, Reklambyuro MMF, 1968.

4. Smolyankin, T. S. "Studies on the Effects of Structural Peculiarities of Cargo Compartments in Marine Vessels on the Volume and Intensity of General Cargo Handling," author's abstract of the dissertation for the Degree of Candidate of Technical Sciences, Odessa, OIIMF [Odessa Institute of Engineers of the Maritime Fleet], 1958.

5. Layner, S. V. "Methods for Analysis of the Operational and Ecomonic Effectiveness of General-Purpose Dry Cargo Vessels," TRUDY TsNIIMF [Central Scientific Research Institute of the Maritime Fleet], No 84, Leningrad, Transport, 1967.

UDC 623.828:667.63.003.1

METHODS FOR ECONOMIC EVALUATION OF THE NEED IN AND EFFECTIVENESS OF NEW
VARNISHES AND PAINTS FOR MARITIME TRANSPORTATION VESSELS   pp 71-80

[Article by V. I. Krayev, Candidate of Economic Sciences, and I. N. Klurfel'd]

Until recently, the determination of future needs in varnishes and paints
was based on establishing methods of computing current needs on the prinicple
of direct dependence of the growth rate of the needs in materials on the
growth rate of the fleet tonnage. The products list and the need in new
materials were not substantiated economically, or were substantiated with-
out consideration for all factors affecting economic indexes of the oper-
ation of maritime transportation vessels.

In order to determine the economically substantiated future needs in syn-
thetic materials, it was recommended to proceed from the necessity of cal-
culating three levels: technically possible, economically effective, and
technically necessary [1]. The content of the concept "technically neces-
sary need," as a purely technical category, was artificially separated from
the economic factors.

It is more correct to determine the future needs in varnishes and paints for
maintaining and operating vessels of the maritime fleet simultaneously on
the basis of technical and economic computations, selecting the most effec-
tive variants in advance. The future needs during the planned period will
be composed of the needs in materials which are already being produced with
consideration for the increase in the volume of their use and the needs in
new economically effective materials.

Such methodological approach makes it possible to determine the real needs
in varnishes and paints for the vessels of the maritime fleet based on the
appropriate technical and economic factors.

As is known, the main means of protecting marine vessels against corrosion
and fouling by algae and microorganisms are varnish and paint protective
coatings. Special requirements placed upon vessel paints are based on
various conditions of their operation depending on the location of the ves-
sel surfaces to be protected (underwater and above-water parts of the hull,
superstructures and interior areas, cargo holds, tanks, etc) and the external

71

factors affecting them. Therefore, in spite of the rapid development of the chemical industry, no universal coatings have, as yet, been developed that could satisfy all requirements and could be used for painting any vessel surface. Due to these facts, in selecting schemes of protective coatings, it becomes necessary to consider technological and operational properties of various primers and paints included in the painting scheme in each case.

In order to determine economically substantiated needs in new varnishes and paints intended for use in maintenance docking, repairs, and operation of marine vessels, it is necessary, first of all, to select optimal schemes of protective coatings for all painted surfaces of the vessel.

It is recommended to select the most effective schemes of protective coatings by the minimum of annual proportional costs according to the expression

$$P_{ij} = S_j \left(\sum_{i=1}^{n} q_i c_i + \sum_{i=1}^{n} T_i a \right) \frac{12}{t_i} = \min, \tag{1}$$

where P_{ij} -- costs of painting by a scheme with the i-th type of coating per 1 ton of cargo-carrying capacity of the j-type of the cargo fleet (for the passenger fleet -- per 1 ton of the gross registered capacity), rubles;

S_j -- proportionate area of the painted surface of the j-type fleet, m^2/ton of cargo-carrying capacity;

q_i -- consumption of the i-type coating with consideration for the number of layers, kg/m^2;

c_i -- cost of i-type of coating, rubles/kg;

T_i -- labor-intensiveness of painting with i-type coating, man-hr/m^2;

a -- expenses on labor (including overhead expenses), rubles/man-hr;

t_i -- lifetime of the i-type coating, months;

n -- number of types of varnishes and paints included in the scheme.

As has been mentioned before, due to the differences in the operating conditions, different varnishes and paints are used for individual areas of the vessel. Consequently, the proportionate consumption of materials and labor intensiveness of their application to the surfaces will differ. Moreover, analysis of structural and architectural characteristics of marine cargo vessels of various purposes and dimensions shows that the proportionate areas of painted surfaces also differ for different types of fleet. Thus, the above factors predetermined the selection of optimal schemes of new protective coatings, on the one hand, by individual types of fleet (dry cargo vessels, tankers, etc) and, on the other hand, by individual groups of painted surfaces. If necessary, vessels for the same purpose are grouped by tonnage groups.

Indexes of proportionate areas by the types of fleet and types of painted surfaces are established by processing painting reports on various types of vessels by the methods of mathematical statistics. The proportionate consumption and the lifetime of new types of materials, as well as the labor

72

intensiveness of their application are computed on the basis of the general-
ization of the experimental data on their use. The proportionate cost of
varnish and paint coatings is taken in accordance with the current wholesale
prices or according to the expected costs. Since the materials of new coat-
ings do not differ fundamentally with respect to technology of their manu-
facturing and the method of application from the ones they are replacing,
the capital investments into the production of the materials in the con-
nected industry and into the application of the coatings at ship repair yards
and vessels change insignificantly, and can be disregarded in computations
of the economic effectiveness.

After the determination of the optimal schemes of new protective coatings
for various painted surfaces of various types of fleets, the effectiveness
of their utilization is evaluated in comparison with the existing coatings.

In a general form, it is recommended to evaluate the effectiveness by the
existing methods on the basis of the difference of the calculated expenses
(3 = C+EK) per a unit of product.

Specific characteristics of the application of protective coatings for
painting marine vessels determine the necessity of modifying the formula
for defining the economic effectiveness recommended by standard methods.
The economic effectiveness of using new schemes of protective coatings is
determined by many factors whose number depend on the purpose of the coat-
ing and its effect on the operation properties of the painted objects [2].
Consequently, all varnish and paint coatings for marine vessels are divided
into two groups. The first group includes protecting coatings whose intro-
duction causes changes only in the average annual expenses on the materials
and their application. This group includes coatings for the above-water
parts of vessels, superstructures, decks, inner living and service quarters,
cargo holds, etc. The economic effectiveness of the tuilization of coatings
of this group is determined by the lifetime of the coating, the labor costs
of its application, the consumption norms for varnishes and paints per 1 m2
of surfaces, and the prices of the varnishes and the paints. The second
group includes coatings whose introduction, in addition to the above, also
affects the changes in the operational properties of the painted vessels.
It includes anticorrosion and antifouling coatings for the underwater part
of the vessel and the variable waterline area, and anticorrosive coatings
for the inner surfaces of tanks. The economic effectiveness of the applica-
tion of coatings of this group, along with the above-mentioned, is deter-
mined by an increase in the speed of vessels or the average annual operating
period, and, consequently, by the carrying capacity of the fleet and lower
expenses on the maintenance of the vessel.

The economic effectiveness of the use of new protective coverings which do
not bring about any changes in the productivity of the vessels of the trans-
portation fleet is computed by the expression

$$\mathcal{Э}^I = \sum \mathcal{Э}^I_j = \mathcal{Э}^I_c + \mathcal{Э}^I_{\text{и}} + \mathcal{Э}^I_{\text{п}},$$

(2)

73

where $\sum \mathfrak{I}_j^I$ is the total annual saving for the entire fleet;

$\mathfrak{I}_c^I, \mathfrak{I}_{\text{н}}^I, \mathfrak{I}_{\text{n}}^I$ is the annual saving for the dry-cargo, tanker, and passenger transportation fleet.

The size of the economic effect on each type of fleet for this group of coatings is determined only by the differences in the expenses on materials and wages; proportionate capital investments for vessels do not change because the carrying capacity of the vessel remains the same.

The surfaces of the above-water sides, superstructures, inner living and service quarters etc, are, as a rule, painted according to an incomplete scheme. Along with this, the presence of individual sections subjected to intensive corrosion makes it necessary to paint them according to the complete scheme. These surfaces are protected chiefly by the crews of the vessels under operating conditions. When computing the economic effectiveness of the use of new paints and varnishes, the labor intensity of painting by the vessel's crew must not be taken into consideration if it does not lead to a reduction in the deck crew; the expenses of the shipyard on painting the vessel must be distributed over the entire period of shipyard maintenance.

Having substituted full values of the components of formula (1) in formula (2) and having performed the necessary conversions, we shall obtain an expression for computing the annual economic effect from the use of new protective coatings of surfaces of the first group for individual types of fleet:

for painting according to the complete scheme

$$\mathfrak{I}_j^I = \beta S_j \sum D_j \left[12 \left(\frac{\sum_{i=1}^{n} q_i^{\text{т}} c_i^{\text{т}}}{t_i^{\text{т}}} - \frac{\sum_{i=1}^{n} q_i^{\text{c}} c_i^{\text{c}}}{t_i^{\text{c}}} \right) + \frac{a}{z} \left(\sum_{i=1}^{n} T_i^{\text{т}} - \sum_{i=1}^{n} T_i^{\text{c}} \right) \right] \text{ rubles;} \tag{3}$$

for painting according to an incomplete scheme

$$\mathfrak{I}_j^I = S_j \sum D_j \left[12 \left(\frac{\sum_{i=1}^{m} q_i^{\text{т}} c_i^{\text{т}}}{t_i^{\text{т}}} - \frac{\sum_{i=1}^{m} q_i^{\text{c}} c_i^{\text{c}}}{t_i^{\text{c}}} \right) + \frac{a}{z} \left(\sum_{i=1}^{m} T_i^{\text{т}} - \sum_{i=1}^{m} T_i^{\text{c}} \right) \right] \text{ rubles} \tag{4}$$

where β -- is a coefficient allowing for the surface area painted according to a complete scheme (determined by processing the data of shipyard and vessel documents by the methods of mathematical statistics).

74

n, m -- number of types of materials used for the complete and incomplete schemes of painting, respectively;

z -- time between shipyard maintenance jobs, years; $z = 2$; indexes "T" and "c" mean traditional and synthetic materials, respectively.

Inner surfaces of cargo holds, tanks and other containers (except for the cargo tanks of oil tankers) are, as a rule, painted according to a complete scheme.

The annual economic effect from using protective coatings for painting these surfaces is computed by the formula

$$\mathcal{3}_j^I = 12 S_j \sum D_j \left[\left(\frac{\sum_{i=1}^n q_i^T c_i^T}{t_i^T} - \frac{\sum_{i=1}^n q_i^c c_i^c}{t_i^c} \right) + a \left(\frac{\sum_{i=1}^n T_i^T}{t_i^T} - \frac{\sum_{i=1}^n T_i^c}{t_j^c} \right) \right] \text{ rubles.} \tag{5}$$

The economic effectiveness from the use of new anticorrosion and antifouling coatings (for the underwater parts of vessels, variable waterline areas, and cargo tanks) causing changes in the productivity of a vessel of the transportation fleet is computed by the expression

$$\mathcal{3}^{II} = \sum \mathcal{3}_j^{II} = \mathcal{3}_c^{II} + \mathcal{3}_{\text{н}}^{II}. \tag{6}$$

The use of the above-mentioned coverings in passenger vessels does not change their carrying capacity because they work on a schedule.

The use of new long-lasting antifouling coatings for the underwater part and the variable waterlines of vessels (if the length of the period between the drydocking times of the vessels established by the Maintenance Regulations is maintained) reduce the losses in the speed due to fouling.

The annual economic effect of this group of protective coatings for the dry cargo and tanker fleets is

$$\mathcal{3}_j^{II} = \mathcal{3}_j^I + \mathcal{3}_j^v, \tag{7}$$

where $\mathcal{3}_j^I$ -- the annual economic effect from the changes in the expenses on materials and the wages of shipyard workers;

$\mathcal{3}_j^v$ -- the annual economic effect from the increase of the average speed of vessels of a given fleet type

The painting of the underwater part and the variable waterline area of a vessel is done according to the complete scheme both during the period of the preventive maintenance, and during shipyard repairs. Moreover, during

75

the vessel's operation, due to the low stability of protective coatings and their mechanical damages, the variable waterline area must be repainted according to an incomplete scheme several times a year by the vessel's crew.

If the length of the period between dockings $t_{док}$ and the above-mentioned factors are maintained, it is recommended to determine the annual economic effect from the use of new anticorrosion and antifouling coatings for individual types of fleet by the following formula:

for the underwater part of a vessel:

$$\mathcal{Э}_j^{\text{I}} = \frac{12 S_j \Sigma D_j}{t_{док}} \left[\left(\sum_{i=1}^n q_i^{\text{т}} c_i^{\text{т}} - \sum_{i=1}^n q_i^{\text{c}} c_i^{\text{c}} \right) + a \left(\sum_{i=1}^n T_i^{\text{т}} - \sum_{i=1}^n T_i^{\text{c}} \right) \right] \text{ Rubles;} \tag{8}$$

for the variable waterline area:

a) when painting according to a complete scheme -- by expression (8);

b) when painting according to an incomplete scheme:

$$\mathcal{Э}_j^{\text{I}} = S_j \sum D_j \left[\sum_{i=1}^m q_i^{\text{т}} c_i^{\text{т}} \left(\frac{12 - t_i^{\text{т}}}{t_i^{\text{т}}} \right) - \sum_{i=1}^m q_i^{\text{c}} c_i^{\text{c}} \left(\frac{12 - t_i^{\text{c}}}{t_i^{\text{c}}} \right) \right] \text{ rubles} \tag{9}$$

The second component in formula (7) is the economic effect from the increase in the speed of vessels in a given type of fleet, which is computed by the following formula:

$$\mathcal{Э}_j^v = \overline{\Delta \mathcal{Э}_j^{\text{п}}} \sum Q l_j, \tag{10}$$

where $\Delta \mathcal{Э}_j^{\text{п}}$ is the decrease in the normalized expenses for the j-type fleet, rubles/ton-mile.

$\sum Q l_j$ is the volume of transportation production achieved during the rated year by the j-type fleet, ton-mile.

The lowering of the normalized expenses per production unit for cargo vessels resulting from the increase in the speed is determined by the formula

$$\Delta \mathcal{Э}_j^{\text{п}} = \left(\frac{R_{\text{x}}}{D k_{\text{г}} v^{\text{т}}} + 0{,}15 \frac{C_{\text{стр}}}{T_{\text{э}} D k_{\text{г}} v^{\text{т}}} \right) - \left(\frac{R_{\text{x}}}{D k_{\text{г}} v^{\text{c}}} + 0{,}15 \frac{c_{\text{стр}}}{T_{\text{э}} D k_{\text{г}} v^{\text{c}}} \right) \frac{\text{rubles}}{\text{ton-mile}}, \tag{11}$$

where R_{x} is the cost of daily maintenance of the moving vessel, rubles/day; C_{CTP} is the construction cost of the vessel, rubles;

76

D is the cargo deadweight, tons;

k_{Γ} is the coefficient of the utilization of the vessel's cargo-carrying capacity;

v^T, v^c is the average daily speed of the vessel (gross) for the traditional and the new coating, respectively, miles/day;

T_3 is the length of the vessel's operating period in a year, days.

Having transformed formula (11), we obtain

$$\Delta 3_j^{\pi} = \frac{1}{D k_{\Gamma}}\left(R_x + 0.15\frac{C_{c\tau p}}{T_9}\right)\left(\frac{1}{v^{\tau}} - \frac{1}{v^c}\right) \text{rubles/ton-mile} \tag{12}$$

Application of new coatings for the protection of inner surfaces of the tanks of tankers against corrosion reduces the intensiveness of their corrosive wear and tear and, consequently, the volume of maintenance. This, in turn, reduces the average annual expenses on maintenance and the time necessary for cleaning the tanks before loading. The economic effect from the use of the above-mentioned coatings on these vessels is determined by the expression

$$\Theta_{\textrm{н}}^{\textrm{III}} = \Theta_{\textrm{н}}^{\textrm{I}} + \Theta_{\textrm{н}}^{\textrm{p}} + \Theta_{\textrm{н}}^{\textrm{м}} \text{ rubles/year} \tag{13}$$

where $\Theta_{\textrm{н}}^{\textrm{p}}$ is the annual saving from the reduction of maintenance costs caused by the corrosion of tanks, rubles;

$\Theta_{\textrm{н}}^{\textrm{м}}$ is the annual effect from the increase in the intensiveness of the processing of vessels in ports, rubles.

The annual saving from the changes in the expenses on materials and wages of shipyard workers $\Theta_{\textrm{н}}^{\textrm{I}}$ is determined by formula (5).

The annual saving from the reduction of the maintenance expenses due to corrosion is determined as an average annual difference in the expenses on maintenance with the use of the old and new coatings:

$$\Theta_{\textrm{н}}^{\textrm{p}} = \Delta C_{\textrm{н}}^{\textrm{p}} \sum D_{\textrm{н}} \text{ rubles} \tag{14}$$

where $\Delta C_{\textrm{н}}^{\rho}$ is the reduction of the specific average annual expenses on the maintenance of tanks due to corrosion, rubles/ton of cargo-carrying capacity.

The annual economic effect from the increase in the intensiveness of the processing of tankers in ports is determined by the expression

$$\Theta_{\textrm{н}}^{\textrm{м}} = \Delta 3_{\textrm{н}}^{\pi} \sum Q l_{\textrm{н}}. \tag{15}$$

The lowering of normalized expenses $\Delta 3_{\textrm{н}}^{\pi}$ per unit of product resulting from the increase in the intensiveness of the processing of tankers in ports is

77

determined by analogy with formula (11) according to the following expression.

$$\Delta 3_{\text{н}}^{\text{п}} = \frac{2}{l} \left(R_{\text{ст}} + 0{,}15 \frac{C_{\text{стр}}}{T_{\text{э}}} \right) \left(\frac{1}{M^{\text{т}}} - \frac{1}{M^{\text{с}}} \right) \text{ rubles/ton·mile} \tag{16}$$

where l -- average transportation range of 1 ton of cargo, miles;

    R_{CT} -- cost of vessel's maintanance while in port, ruble/day;

    M^{T} and M^{C} -- average daily intensiveness of vessel's processing in ports with the use of traditional and new protective coatings for tanks, respectively, ton/day.

The total annual economic effect from using new protective coatings for the transportation fleet is defined as

$$\vartheta = \vartheta^{\text{I}} + \vartheta^{\text{II}} + \vartheta^{\text{III}}.$$

Having performed the appropriate computations according to the recommended formula and having analyzed the obtained results, we determine the effective schemes of new varnish and paint coatings and, by them, established the economically substantiated need for a year.

The need in various varnishes and paints is determined by groups of painted surfaces for the appropriate type of fleet from the conditions of the application of protective coatings:

Over the entire area according to a complete scheme (underwater part of the vessel, cargo holds, tanks, etc);

over the entire area according to a complete and an incomplete schemes (variable waterline area);

over a part of the area according to a complete scheme and over the entire area according to an incomplete scheme of painting (above-water sides, superstructures, inner living and service quarters, engine and boiler rooms, etc).

Proceeding from these conditions, the annual need in new varnishes and paints is computed by the following formulas:

-- for the underwater part of the vessel

$$Q^{\text{I}} = \sum Q_{ij}^{\text{I}} = S_j \sum D_j \sum_{i=1}^{n} q_i \frac{12}{1000 t_{\text{док}}} \text{ ton/year} \tag{17}$$

-- for cargo holds, tanks and other containers, the formula remains the same, but instead of the time between the dockings $t_{\text{док}}$, the lifetime of the protective coating t_i is considered;

78

-- for variable waterline area at $t_i < t_{ДОК}$;
    a) when painting according to a complete scheme -- by formula (17);
    b) when painting according to an incomplete scheme:

$$Q^{II} = \sum Q_{ij}^{II} = S_j \sum D_j \sum_{i=1}^{m} q_i \frac{1}{1000} \left(\frac{12 - t_i}{t_i} \right) \quad \text{ton/year} \tag{18}$$

-- for above-water sides, superstructures, inner living and service quarters, etc:
    a) when painting according to a complete scheme

$$Q^{III} = \sum Q_{ij}^{III} = \beta S_j \sum D_j \sum_{i=1}^{n} q_i \frac{12}{1000 t_i} \quad \text{ton/year} \tag{19}$$

    b) when painting according to an incomplete scheme

$$Q^{III} = S_j \sum D_j \sum_{i=1}^{m} q_i \frac{12}{1000 t_i} \quad \text{ton/year} \tag{20}$$

The total annual need in individual types of new varnishes and paints for the transportation fleet is determined by the following formula

$$Q = Q^{I} + Q^{II} + Q^{III} \quad \text{ton/year}$$

In conclusion, it should be pointed out that the following must be taken into consideration in determining the economic effectiveness of the use of new varnish and paint coatings for the protection of marine transportation vessels against corrosion and fouling:

1) consolidation of norms which reflect peculiarities characteristics of vessels of different purposes is permissible only when the differences in their values for individual types of fleet do not exceed 5-10 percent;

2) average annual expenses on repairs caused by corrosion are determined on the basis of the report data of ship repair yards and steamship lines and the results of planning and research projects;

3) the economic effect is determined in application to representative vessels of each type of fleet which are selected on the basis of the composition of the cargo fleet planned for the rated year as vessels of new types whose cargo-carrying capacity is the closest to the mean values; and the composition of the passenger fleet is determined by the mean values of the gross registered tonnage;

4) the operational and economic indexes of vessels are taken for the first rated year of the period that is being examined in accordance with the planned level, and for the last rated year and later -- by the materials of long-range studies on the development of the marine transportation system.

79

BIBLIOGRAPHY

1. "Methods and Procedures for Studies on the Topic 'Elaboration of the Ecomonic Problems in the Development of the Chemical Industry and Use of Chemicals in the National Economy in 1971-1975, and Predictions to 1980'", Department of Economics, USSR Academy of Sciences, Scientific Council "Economic Problems of the Chemization of the National Economy," Moscow, NIITEKhIM [Scientific Research Institute of Technical and Economic Research of the State Committee of the Council of Ministers, USSR, for Chemistry], 1967.

2. Krayev, V. I. "Methods for Determining Economic Effectiveness of Research Work," TRUDY TsNIIMFa [Transactions of the Central Scientific Research Institute of the Maritime Fleet], No 84, Leningrad, Transport, 1967.

OPTIMAL DISTRIBUTION OF FREIGHT VOLUME AND TONNAGE AMONG BASIN PORTS   pp 80-83

[Article by L. A. Chvertkin, Candidate of Naval Sciences]

Determination of the freight traffic volume for a basin as a whole or for
a group of ports for the following planned period is based on the analysis
of certain factual prehistory which would ensure the solution of national
economic problems, the developed traditional transportation connections,
and the handling capacity of the ports, but the optimal transportation poten-
tialities of the fleet are not taken into consideration here. In the mean-
time, the optimization of the transportation process requires simultaneous
examination of all its elements.

In the problem examined here, we shall proceed from the idea that all ports
of the basin are equivalent from the viewpoint of their transportation con-
nections. This assumption is fully justifiable if we consider that there
is always the possibility of grouping freight traffic on the basis of iden-
tital transportation connections. We shall assume that the distribution of
the shipping volume among the ports will be optimal if it ensures the real-
ization of at least the average potentialities of the fleet depending on
the accepted criterion. This makes it possible to connect the expected re-
sult with the direct organization of the fleet operations. There may arise
situations shown in Table 1.

Table 1

Available tonnage	Handling capacity of ports	
	Unlimited	Limited
Unlimited	Variant I	Variant II
Limited	Variant III	Variant IV

Limitations shown in Table 1 should be understood in the following manner.
The number of vessels with respect to types will be considered unlimited if
we are to solve a problem on shipping which does not require the involvement
of the entire available tonnage. Otherwise, the tonnage will be considered
limited. The handling capacity of the ports will be evaluated in exactly
the same way considering it limited if the amount of freight to be transported
is smaller than the amount which the port can process, and unlimited other-
wise. In this work, we shall examine variants I and II, because the remain-
ing variants are connected with the arrangement of the fleet.

In variant I, no limitations are imposed either on the tonnage or on the ports. The problem is to determine such proportions of the shipping volume among the ports and types of vessels which would ensure the realization of at least their average potentialities. This problem can be solved by the methods of the theory of games. In this game, a ship owner is the 1st player who tries to maximize, for example, his profit. A sender of freight can be the 2nd player who is interested in minimizing his expenses. The payoff in this game can be net income from the transported freight or some other criteria. We shall assume that the payoff is net income obtained by the vessel in its voyage along a definite route. As it is accepted in the theory of games and as it follows from the idea of the problem, the payoff will be given to the 1st player by the 2nd player. Then, if there are m types of vessels and n ports, then, according to the theory of games, the inequalities and equalities whose matrix form at nonnegative variables x and y is as follows must be valid:

$$\left. \begin{array}{c} xA \geqslant v, \\ Ay \leqslant v, \end{array} \right\} \tag{1}$$

where $A = \|a_{ij}\|$ -- payoff matrix m x n;

$x = (x_1, x_2, \ldots, x_m)$ -- row vector from the strategy space x of the 1st player;

$y = (y_1, y_2, \ldots, y_n)$ -- row vector from the strategy space y of the 2nd player;

v -- value of game.

The following conditions must be fulfilled:

$$\left. \begin{array}{c} \sum_{i=1}^{m} x_i = 1, \\ \sum_{j=1}^{n} y_j = 1. \end{array} \right\} - \leqslant \tag{2}$$

Thus, the game made up by us will be determined by the triplet (x, y, v), and the strategies of the 1st and 2nd players with the frequencies of the utilization of types of vessels by the 1st player and the ports of the basin by the 2nd player can be considered as optimal proportions for the distribution of the transportation resources by the players. If the players maintain their optimal strategies, i.e., observe the optimal proportions, then, in the course of a long period of the fleet operation, it will be possible to realize a certain amount of net income:

$$E = E(x, y) = \sum_{i=1}^{m} \sum_{j=1}^{n} x_i a_{ij} y_j. \tag{3}$$

According to the conditions of (1), a payoff of not less than E will be ensured for the 1st player using strategies x_i, and a payoff of not more than E will be ensured for the 2nd player using strategy y_i. Let us illustrate this on the following example.

In order to ship freight from port A to ports B and C, vessels of two types are used. It is known from the operating experience of these vessels that, on the average, hundreds of rubles of net income was obtained by these ships in one voyage along different routes (see Table 2).

Table 2

Types of vessels	Traffic scheme	
	A→ B	A →C
1st	26	30
2nd	28	27

It is required to determine how to distribute the shipping volume between ports B and C and between vessel types 1 and 2 so that the net income during the planned period would not be any lower than a certain average value E. In order to solve this problem, let us set up the following inequalities and equalities in accordance with expressions (1) and (2):

$$\left.\begin{array}{c} 26x_1 + 28x_2 \geqslant v, \\ 30x_1 + 27x_2 \geqslant v, \\ x_1 + x_2 = 1, \end{array}\right\} \quad (4) \qquad \left.\begin{array}{c} 26y_1 + 30y_2 \leqslant v, \\ 28y_1 + 27y_2 \leqslant v, \\ y_1 + y_2 = 1. \end{array}\right\} \quad (5)$$

The solution of systems (4) and (5) will be:

$$x_1 = 0{,}2; \qquad y_1 = 0{,}6;$$
$$x_2 = 0{,}8; \qquad y_2 = 0{,}4; \qquad v = 27{,}6.$$

The obtained result should be interpreted in the following way: cargoes from port A must be dispatched to ports B and C in the proportion of 6:4, and the carrying capacity of vessels by the types must be distributed in the proportion of 2:8. This distribution must ensure for the vessels, on the average of a long period, a net income of 27.6 (hundreds of rubles) in one trip. Knowing the distribution of the volume of shipping and the tonnage, it is easy to determine the required number of trips for vessels for each type during the planned period and to organize fleet operations so as to obtain the desired financial result.

We have examined the first variant when the handling capacity of the ports was considered unlimited; in practice, it is not always true. When the vessel turnover in the ports is limited and different (variant II), the established proportion for the distribution of shipping between ports must be taken for one berth. And the entire volume of shipping must be distributed in this case in proportion to the norms for simultaneous cargo handling established for these ports.

THE USE OF METHODS OF MATHEMATICAL STATISTICS FOR DETERMINING PLANNED INDEXES
OF THE OPERATIONS OF SELF-SUPPORTING VESSELS   pp 83-93

[Article by L. N. Lipatov]

The new system of trip planning and profit and loss accounting for ships on
routes to foreign countries makes it possible to make a wide use of the me-
thods of mathematical statistics in the organization and analysis of fleet
operations. Under modern conditions, analysis must be based on a clear or-
ganization of accounting, statistics, reports, and scientifically substan-
tiated criteria of economic interrelations.

This article is based on the reports of trips made by 37 vessels of the
Baltic Steamship Lines which were changed to the new system of trip planning
and profit and loss accounting. Using the methods of mathematical statistics
for processing the trip reports and financial reports for 1968, the author
set three goals for himself:

1) to evaluate the quality of the analytic work on the vessels with respect
to calculating the trip assignments, to select and define a statistical mo-
del for describing errors in the trip reports, and to analyze the method of
using this model in solving practical problems;

2) to study the degree of connection between the income and expenses, and
to define its form and quantitative expression;

3) to determine the significance of the index and the income level in rela-
tion to the net currency gain for vessel-days.

As is known, the trip is the basis of vessel planning. The norms of trip
assignments include the most important indexes determining their planned
length and gross income. Knowing the norms and elements of a trip assign-
ment, it is possible to organize efficient income and expenditure accounting
aboard the ship correctly. By comparing the income and expenses computed on
ships and processed through the accounting system, it is possible to estab-
lished discrepancies between them. In general, it can be said that these
discrepancies are due to such insignificant factors as accidental errors in
the daily expenses on various items and calculations of the amounts of

freight, differences in the ship's and stevedore dues and other expenses in relation to established norms. Consequently, it is necessary to evaluate the values of these deviations and develop acceptable statistical models for them.

Analysis of the 1968 data for 37 vessels shows that the greatest deviations from the accounting results from +24.8 to -13.4 percent are observed in the computations of expenses. This indicates qualitative nonuniformity of captains' reports. Such differences are considerably smaller in the income of the vessels.

We shall take accounting reports to be true, because the overall picture of the distribution of errors does not change from it.

The absolute values of errors in computing the income vary from -55,000 to +34,000 rubles, and relative discrepancies from -4.50 to +1.6 percent.

Table 1 shows the results of observations for 37 vessels.

<div align="center">Table 1</div>

(1) Расхождения в доходах, %	(2) Число случаев	(3) Вероятность
+2,5 ÷ +1,5	2	0,054
+1,5 ÷ +0,5	11	0,298
+0,5 ÷ —0,5	19	0,513
—0,5 ÷ —1,5	2	0,054
—1,5 ÷ —2,5	2	0,054
—2,5 ÷ —3,5	0	0,000
—3,5 ÷ —4,5	1	0,027

Key: 1. Discrepancies in the income, percent
     2. Number of instances
     3. Probability

The last line shows the probabilities, i.e., the ratio of the instances in each of the intervals to the total number of observations. The data of Table 1 shows that the discrepancies in the income of more than +1.5 percent and less than -1.5 percent occur rather rarely. Discrepancies within the limits from +0.5 to -0.5 percent are most probable. Thus, we have obtained a certain distribution of variable values characterizing the discrepancies in the income.

This variable value is the total result of a large number of small independent influences, therefore, it is possible to expect that it is distributed according to a normal law. Let us determine the parameters of this

distribution by the simplest method of the so-called conditional variants.
For this, let us rewrite Table 1 vertically and introduce the numbers of in-
tegrals in their ascending order, having marked their origin near the middle
of the interval corresponding to the maximum frequency (Table 2).

Table 2

Расхождения в доходах, % (1)	f	κ	κf	$\kappa^2 f$	$\kappa^3 f$	$\kappa^4 f$
+2,5 ÷ +1,5	2	2	4	8	16	32
+1,5 ÷ +0,5	11	2	22	22	22	22
+0,5 ÷ —0,5	19	0	0	0	0	0
—0,5 ÷ —1,5	2	—1	—2	—2	—2	2
—1,5 ÷ —2,5	2	—2	—4	8	—16	32
—2,5 ÷ —3,5	0	—3	0	0	0	0
—3,5 ÷ 4,5	1	—4	—4	16	—64	256
(2) Итого ..	37	—	16	56	—44	342

Key: 1. Discrepancies in the income, percent
     2. Total

The most important characteristic of the distribution center is the mathe-
matical expectation

$$\bar{x} = k_0 + \frac{i\Sigma kf}{f} = 0,433\%,$$

where $\bar{x}$ is the mean value of the relative error;
      k is the number of the interval;
      i is the value of the interval;
      f is the frequency.

Then, let us determine the first distribution moments: $m_1 = 0.43$, $m_2 = 1.51$,
$m_3 = -1.19$, $m_4 = 9.26$.

Dispersion σ^2, or the second moment in relation to the medium one, is the
dispersion index:

$$\sigma^2 = \mu_2 = m_2 - m_1^2 = 1,32\%.$$

The root-mean-square deviation $\sigma \approx 1.15$ percent.

In order to obtain the values of asymmetry As, let us write::

whence

$$\mu_3 = m_3 - m_1(2\mu_2 - m_2) = -2,98,$$

$$As = \frac{\mu_3}{\sigma^3} = -\frac{2,98}{1,153} = -1,96.$$

86

This indicates the presence of a considerable negative assymetry in the distribution of relative errors.

Excess E_x (the high peak index) is determined from the expression

$$\mu_4 = m_4 - 4m_3 m_1 + 6m_2 m_1^2 - 3m_1^4 = 6{,}54,$$

whence

$$E_x = \frac{\mu_4}{\sigma^4} - 3 = 0{,}76.$$

Then, let us determine to what degree it is possible to consider the distribution of the values of discrepancies between the amounts of income as corresponding to the normal law. For this, let us compute theoretical frequencies and compare them with the frequencies of the empirical series (Table 3).

<div align="center">Table 3</div>

(1) Расхождения в доходах, %	f	κ	$\kappa - \bar{x}$	$\frac{\kappa - \bar{x}}{\sigma} = t$	$f(t)$	$\frac{\Sigma ft}{\sigma}$	$f(t)$
+2,5 ÷ +1,5	2	+2	1,57	1,36	0,1582	5,2	5
+1,5 ÷ +0,5	11	+1	0,57	0,495	0,3530	11	11
+0,5 ÷ —0,5	19	0	—0,43	0,372	0,372	12	12
—0,5 ÷ —1,5	2	—1	—1,43	1,25	0,1826	6	6
—1,5 ÷ —2,5	2	—2	—2,43	2,16	0,0387	1,5	2
—2,5 ÷ —3,5	0	—3	—3,43	2,99	0,0044	0,01	0
—3,4 ÷ —4,5	1	—4	—4,43	3,86	0,0034	0,01	0

Key: 1. Discrepancies in income, percent

Let us construct a polygon of the empirical and theoretical distribution of the values of discrepancies in the income (Figure 1).

——— empirical frequency
- - - - theoretical frequency
Figure 1
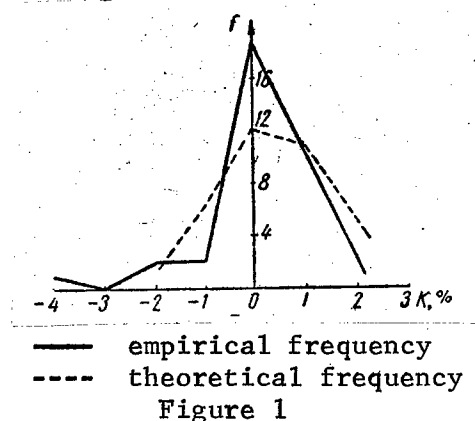
Let us determine Kolmogorov's goodness-of-fit test λ for evaluating the correspondence of this empirical distribution to the normal distribution (Table 4).

<div align="center">Table 4</div>

Расхождения в доходах, % (1)	(2) Частота распределения		(5) Накопление частоты		(6) Абсолютное значение разностей $\Sigma f - \Sigma f(t)$
	(3) фактическая f	(4) теоретическая $f(t)$	(5) фактическая Σf	(4) теоретическая $\Sigma f(t)$	
+2,5 ÷ +1,5	2	5	2	5	3
+1,5 ÷ +0,5	11	11	13	16	3
+0,5 ÷ —0,5	19	12	32	28	4
—0,5 ÷ —1,5	2	6	34	34	0
—1,5 ÷ —2,5	2	2	36	36	0
—2,5 ÷ —3,5	0	0	36	36	0
—3,5 ÷ —4,5	1	0	37	36	1

Key: 1. Discrepancies in the income, percent
2. Distribution   frequency
3. Factual
4. Theoretical
5. Frequency growth
6. Absolute values of differences

As can be seen from the table, the maximum difference between the factual and theoretical frequencies is equal to 4. Consequently, λ = 0.65.

From the table of probabilities for λ = 0.65, we obtain the probability of the presence of closeness between the empirical and theoretical distribution P λ = 0.8. Thus, it is possible to assert with probability P λ = 0.8 that the distribution of the discrepancy values of the sum of the income follows the normal law.

An analogous method is used to determine the parameters of the distribution of a random variable characterizing the discrepancies in the calculations of expenses for 37 vessels during the review period (Table 5).

Mathematical expectation x = 3.04 percent, dispersion σ^2 = 46 percent, root-mean-square deviation σ = 6.8 percent, asymmetry As = +0.92.

The theoretical and factual frequencies differ greatly.

Kolmogorov's goodness-of-fit test is:

$$\lambda = \frac{D}{\sqrt{\Sigma f}} = \frac{9}{\sqrt{37}} = 1,46, \text{ whence } P\lambda = 0,03.$$

<div align="center">88</div>

Table 5

(1) Величины расхождений в расходах, %	f	k	kf	k^2f	k^3f	k^4f
+25÷+20	1	5	5	25	125	625
+20÷+15	0	4	0	0	0	0
+15÷+10	0	3	0	0	0	0
+10÷+5	0	2	0	0	0	0
+5÷0	10	1	10	10	10	10
0÷—5	13	0	0	0	0	0
—5÷—10	8	—1	—8	8	—8	8
—10÷—15	4	—2	—8	16	—32	64
—15÷—20	1	—3	—3	9	—27	81
(2) Итого . . .	37	—	—4	68	68	707

Key: 1. Values of discrepancies in expenses, percent
     2. Total

Consequently, it is possible to assert that the distribution of discrepancies in the sums of expenses does not correspond to the normal law.

Theoretical analysis of the essence of the transportation process makes it possible to establish a possible causal relationship between the expenses and income of vessels from transporting cargoes in a general form, but it does not give an answer to the question regarding the realization of this theoretical relationship under concrete conditions of vessel operations. Statistical processing of all income and expenses for 37 vessels makes it possible not only to establish this relationship, but also to give its quantitative characteristic, which is very important for improving the planning of fleet operations. For example, if it is planned to increase the amount of income from foreign shipping, then it is possible to establish approximate amounts of expected expenses and the net currency gain.

Let us group the data on the particular values of income and expenses by the types of vessels and write them in a comparative form. If we assume, conventionally, that the income is a factorial characteristic X which causes the expenses to change, then, the resultant characteristic Y changing under the effect of the factorial characteristic will be the expenses.

In order to calculate the correlation coefficient and the parameters of the correlation equation, let us summarize the data in Table 6.

$$\bar{x} = \frac{\Sigma x}{n} = 1,41;$$

$$\bar{y} = \frac{\Sigma y}{n} = 0,76.$$

Table 6

Типы судов (1)	Доходы, тыс. руб. (2)	Расходы, тыс. руб. (3)	Отклонение индивидуальной величины от средней (4)		$dx \cdot dy$	Квадрат отклонений (5)	
			$x - \overline{x} = dx$	$y - \overline{y} = dy$		dx^2	dy^2
„Новгород" (6)	1,8	0,9	+0,4	+0,14	0,056	0,16	0,0196
„Красноград" (7)	1,5	0,7	+0,1	—0,06	—0,006	0,01	0,0036
„Выборг" (8)	1,7	1,0	+0,3	+0,24	0,072	0,09	0,0576
„Архангельск" (9)	1,5	1,1	+0,1	+0,34	0,034	0,01	0,1156
„Волголес (10)	1,3	0,6	—0,1	—0,16	0,016	0,01	0,0256
„Выборглес" (11)	1,2	0,9	—0,2	+0,14	—0,028	0,04	0,0196
„Игаркалес" (12)	1,1	0,5	—0,3	—0,26	0,078	0,09	0,0676
„Котласлес" (13)	1,1	0,5	—0,3	—0,26	0,078	0,09	0,0676
„Коломна" (14)	1,8	0,8	+0,4	+0,04	0,016	0,16	0,0016
Разные суда (15)	1,1	0,6	—0,3	—0,16	0,048	0,09	0,0256
Итого (16)	14,1	7,6	—	—	0,392	0,75	0,4040

Key:
1. Type of vessels
2. Income, thousand rubles
3. Expenses, thousand rubles
4. Deviation of individual values from the mean value
5. Square deviations
6. "Novgorod"
7. "Krasnograd"
8. "Vyborg"
9. "Arkhangel'sk"
10. "Volgoles"
11. "Vyborgles"
12. "Igarkales"
13. "Kotlasles"
14. "Kolomna"
15. Various vessels
16. Total

Coefficient of correlation

$$r = \frac{\Sigma dx\,dy}{\sqrt{\Sigma d^2 y \Sigma dx^2}} = +0,72.$$

The obtained value r characteristics the presence of direct correlation between the income and the expenses.

The parameters of the correlation equation of a direct line of regression are:

$$b = \frac{\Sigma dx\,dy}{\Sigma dy^2} = 0,52;$$

$$a = \overline{y} - b\overline{x} = +0,03.$$

The regression coefficient b shows the average deviation of the value of the resultant characteristic from its mean value when the factorial characteristic deviates from its mean value by one unit.

90

The equation of the line of regression gives a quantitative characteristics of the form of relationship between the obtained income and the expenses for 10 types of vessels has the following form in our example:

$$\bar{y} = 0,03 + 0,52\bar{x}.$$

Substituting mean values of the income by the types of vessels in this equation, we determine the mean values of the expenses. Using the obtained values of the resultant characteristic, we set up a theoretical line of regression which characterizes the form of correlation between the characteristics under study (Figure 2).
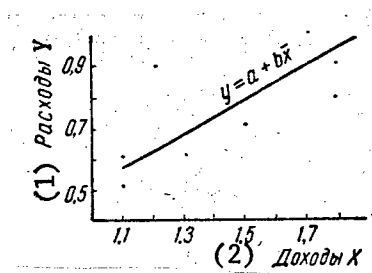

Figure 2
Key: 1. Expenses Y
     2. Income X

In evaluating the fulfillment of trip assignments in the Baltic Steamship Lines, the index "net currency gain per vessel-day," was replaced by the index "income level," because the latter corresponds better to the idea of cost accounting and ensures a more complete computation of all income and expenses.

The index characterizing the income level must be understandable and accessible to all seamen. It must contribute to a maximum utilization of the reserves of the transportation capacity of the fleet, the growth of income, and the observance of strict economy. Moreover, in combination with the bonus system, it must be so rigid that the labor productivity would grow faster than the wages.

We shall try to solve the problem of checking the value of deviation between the two indexes by the methods of dispersion analysis. For this, we shall use, the data on the fulfillment of a plan by 10 types of vessels of the Baltic Shipping Lines in 1968 according to the new and old indexes.

Considering these data as two sets of measurements, we shall determine their dispersions S_1^2 and S_2^2. We have to establish whether they differ considerably or the difference between them is so small that it can be attributed to accidental fluctuations. We shall take $F = S_1^2/S_2^2$ as criterion for evaluating the difference.

91

Comparing the F obtained from observations with R. Fisher's F-distribution, we establish substantial differences between our indexes (Table 7).

<u>Table 7</u>

Типы судов (1)	Выполнение плана по сумме, % (2)		Группа А (5)		Группа Б (6)	
	(3) уровень доходности	(4) чистая валютная выручка на судо-сутки	x	x^2	x	x^2
„Новгород" . (7) . . .	111,5	103,7	1,5	2,25	—6,3	39,7
„Красноград" .(8) . .	111,3	103,0	1,3	1,69	—7	49
„Выборг" .(9)	115,1	111,4	5,1	26	—1,4	1,96
„Архангельск"(10) . .	102,2	106,9	—7,8	61	—3,1	9,6
„Волголес" .(11) . . .	113,8	115	—3,8	10,4	5	25
„Выборглес" . (12) . .	93,5	98,6	—16,5	272	—11,4	130
„Игаркалес" . (13) . .	113,0	118,9	3	9	8,9	79,2
„Котласлес" .(14) . .	112,0	110,0	+2	4	0	0
„Коломна" . . (15) . .	108,0	110,4	—2	4	0,4	0,08
Разные суда .(16) . . .	104,0	103,3	—6	36	—6,7	45
(17) В среднем . . .	109,3	107,5	—15,6	426,34	—18,8	379,54

Key:
1. Types of vessels
2. Fulfillment of the plan with respect to the amount, %
3. Income level
4. Net currency proceeds per vessel-day
5. Group A
6. Group B
7. "Novgorod"
8. Krasnograd"
9. "Vyborg"
10. "Arkhangel'sk"
11. "Volgoles"
12. "Vyborgles"
13. "Igarkales"
14. "Kotlasles
15. "Kolomna"
16. Various vessels
17. Average

group averages

$$\bar{x}_i = \frac{\sum_1^{n=l} x_i}{n_i}; \qquad \bar{x}_A = -1{,}56;$$

overall average

$$\bar{x}_0 = -1{,}72; \qquad \bar{x}_B = -1{,}88.$$

Let us summarize these data in Table 8.

Table 8

Группы (1)	n_i	Σx	Σx^2	$\bar{x}_i$	$\bar{x}_i^2$	$n_i \bar{x}_i^2$
A	10	—15,6	426,34	—1,56	2,43	24,3
B	10	—18,8	379,54	—1,88	3,55	35,5
(2) Итого . . .	20	—34,4	805,88	—1,72	2,95	59,8

Key: 1. Groups
2. Total

The sum of square deviations from the overall average will be:

-- for individual values of x

$$\sum_1^n (x - \bar{x}_0) = \sum x^2 - n\bar{x}_0^2 = 746,8;$$

-- for group averages

$$\sum (\bar{x}_i - \bar{x}_0) = \sum n_i x_i^2 - nx_i^2 = 0,8.$$

The sum of square deviations of individual values of x from the group averages will be 746.0.

The numbers of the degrees of freedom of variations:

overall variation K_0 = n-1 = 20-1 = 19; intergroup variation K_1 = e-1 = 1; intragroup variation K_2 = n-e = 18;

$$S_1^2 = \frac{0,8}{1} = 0,8; \quad S_2^2 = \frac{746,08}{18} = 41,4, \text{ whence } \quad F = \frac{S_2^2}{S_1^2} = 51,7.$$

According to R. Fisher's distribution table, we find table values of F_1 for K_1 = 1 and K_2 = 18: at a 5-percent significance criterion, F_0 = 4.41, and at a 1-percent criterion, F_0 = 8.28.

Comparing the value of F_H = 51.7 obtained from observations with the table values, we see that they differ very much.

The probability of obtaining such a high accidental value of F is very small, consequently, these two indexes are substantially different.

Analysis of the group averages shows that the most economical index is the net currency proceeds per vessel-day.

Further, let us establish the connection between these two indexes by the correlation method. Table 9 shows the fulfillment of the plan for the total of trip assignments according to both indexes minus their average group data.

Correlation coefficient

$$r = \frac{\Sigma dx\,dy}{\sqrt{\Sigma dx^2\,dy^2}} = 0,69.$$

Parameters of the correlation equation of the direct line of regression

$$b = \frac{\Sigma dx\,dy}{\Sigma dx^2} = 0,608;$$

$$a = \overline{y} - b\overline{x} = 1,84.$$

Table 9

(1) Типы судов	$x - \overline{x}$	$y - \overline{y}$	$dx \cdot dy$	dx^2	dy^2
„Новгород" (2) . . .	2,2	—3,8	—8,36	4,85	14,4
„Красноград" .(3). .	2,0	—4,5	—9,00	4,00	20,5
„Выборг" . . .(4). .	5,8	3,9	+22,6	33,6	15,2
„Архангельск" .(5). .	—7,1	—0,6	+4,25	50,3	0,36
„Волголес" . .(6). .	4,5	+7,5	33,7	20,5	56,2
„Выборглес" . .(7). .	—15,8	—8,9	140,05	250,0	79,2
„Игаркалес" . .(8). .	3,7	11,4	41,5	13,7	102,6
„Котласлес" . .(9). .	2,7	2,5	6,76	7,1	6,25
„Коломна" . .(10). .	—1,3	2,9	—3,77	1,69	8,4
Разные суда . .(11). .	—5,3	—4,2	22,6	28,2	17,7
(12) Итого . . .	—	—	252,03	413,94	320,81

Key: 1. Type of vessels   7. "Vyborgles"
     2. "Novgorod"   8. "Igarkales"
     3. "Krasnograd"   9. "Kotlasles"
     4. "Vyborg"   10. "Kolomna"
     5. "Arkhangel'sk" 11. Various vessels
     6. "Volgoles"   12. Total

The regression line equation expresses the quantitative characteristic of the connection between the two indexes, and has the following form in our example:

$$\overline{y} = 1,84 + 0,608\overline{x}.$$

Thus, it is possible to make the following general conclusions.

1. The quality of the accounting for current proceeds on vessels is quite satisfactory. The distribution of errors in captains' trip reports with respect to the proceeds follows the normal law with a probability of 80 percant, mathematical expectation of 0.4 percent, dispersion of 1.3 percent, and root-mean-square deviation of 1.15 percent.

2. Deviations in the expense accounting between the trip reports and accounting reports reach considerable values and are characterized by a considerable spread. It can be asserted that the distribution of errors in the recording of expenses does not follow normal law. This indicates qualitative nonuniformity of submitted materials and requires a more thorough economic analysis.

3. There is a close cause-and-effect relationship between the proceeds and expenses of a vessel. The regression coefficient indicates that, when the proceeds deviate from the average value by 1,000 rubles, it is possible to expect a change in the amount of expenses by 520 rubles in comparison with the average value.

4. Evaluations of the fulfillment of trip plans by the income level and by net currency proceeds per vessel-day differ substantially.

10,233
CSO: 8144/0391   END

95